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THE FREEDOM OF NECESSITY

by the same author

THE SOCIAL FUNCTION OF SCIENCE

THE FREEDOM OF NECESSITY

by

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PREFACE

WE are witnessing in our time one of the greatest changes in all recorded and unrecorded history. No one any longer doubts the importance of the transformation of human society that is now taking place. Interpretations may vary: to some the future is a prospect of dissolution and decay, or of the apocalyptic destruction with the atom bomb. They can see only the disappearance of the values that marked the cultural life of the nineteenth century; they tend, as their forerunners in the early centuries of our era, to escape from the world in mystical or cynical attitudes. But this mood, prevalent as it is among the intellectuals of Western Europe, is countered by another, derived on one hand from the enormously increased control over environment that has come with the full-scale and conscious application of science and on the other by the development of the social forms of the organised working class capable of utilising that science on a large scale, first in the Soviet Union and now in many countries in Europe and Asia.

This positive and hopeful view is that expressed in the following essays: ranging as they do over a considerable period of time and over a wide variety of topics. One unity they necessarily have, that of authorship, but there is another unity which has been impressed on them by the very character of the times; a deliberate unity which attempts to grasp the different aspects of the forces which have moulded our time, to weld them together and to interpret them always in a way which will lead to some control over these forces. In range and scope they derive from my own immediate experience as a scientific worker occupied in the early years of the inter-war period in the academic fields of pure science, increasingly involved political aspects of science as the struggle with Fascism grew nearer and turning towards positive action in the military and technical fields with the war. The variety and depth of experience is consequently progressively increasing; if some of the earlier essays were written now with the experience of the evidence of the last ten years, many would be unrecognisable, but then, if

they were so rewritten, they would lose their value as historical expressions of the impact of those critical events on the mind and work of a scientist.

These events, where they have been deeply felt, have driven many intellectuals and even some scientists to an attitude of negation or escape from the rationalism of the progressive nineteenth century to a general reaction against logical thought or positive material action. To many others they have reinforced the separation between their work, more than ever narrowly compassed by specialisation, and the events of the world outside too vast and distressing to be understood or controlled. Both attitudes tend to emphasise the old division between mind and matter, the world and the spirit. The whole tendency of these essays has been in the opposite direction, towards a union and not a division of human thought and human enterprise. Rational understanding and control of human environment starting from the exact sciences of lifeless matter spread first to the more complex regions of biology and finally, and only in our own time, to the far more complex study of human society and human personality. And these latter studies have reacted on the earlier ones; the existence and development of the physical sciences have come to depend more and more on their integration with other sciences: with their mutual interaction with technical processes and finally with the part they play in the economics and politics of living societies. There is no escape; only by facing and coping with the whole material and human world process is effective thought possible.

The need for comprehensiveness is not limited to analytic thought and action; it is at least as important in creative thought, in the aesthetic, as in the scientific mode. The work of the artist, the experience of the mystic or the religious is genuine in so far as it is a total experience, not excluding the practical needs and the mental climate of the people for whom they feel and to whom they address their message. The unity of the sciences and the arts together with their full extension towards social understanding and social needs is a recurrent theme throughout the essays. The effect of scientific discoveries and of scientific theories on general thought and belief has always been great but with increasing specialisation in the first years of this century it has been difficult to secure the adequate understanding of the new content of physical and biological

sciences on the part of those trained in the humanities. The old interplay between philosophy and science has largely been lost or twisted into discussions which masked actual regression to more primitive forms of belief. The fact is, the cultured person of today, however learned, is relatively more ignorant, that is, knows less of what is known, than at any previous period in history. Only by emphasising the unity of science and the humanities and the need for a far more general scientific culture can this tendency be reversed.

The isolation of the natural sciences needs to be broken down, not only in the field of thought, but quite as much in the field of action. Although progress in the natural sciences was ultimately responsible for most of the great changes that our civilisation has undergone in the last two hundred years, it has not been directly responsible for them in so far as the use of science has been largely brought about by a combination of economic interests in which the scientist has, until very recently, played a small part. The specialisation of sciences here also resulted in a separation between the laboratory and the workshop which were originally two words for the same thing; in the last few years, however, the relations between science and its applications have grown more direct and easy to see. This has brought about a consciousness of the responsibility of scientific workers for the evils as well as the benefits of the present state of the world and the need for them to exercise this responsibility which is the repeated theme of these essays. It involves a concentration on the need for the organisation of science and its relation to the economic and political factors of the time. Many of the essays were written before the war when this was still somewhat of a pious hope. The war, however, gave it a practical reality and we must use all the lessons of the war in order to secure the even more urgently needed benefits of science for peace and to bar once and for all its more horrible and futile use in war. The discovery of the atom bomb is the most striking symbol of this double aspect of science and the reminder that science can no longer with impunity be treated as a neutral force in human affairs.

The practical relation of scientific discovery to human welfare is only one aspect of a much wider unity in which science itself takes its place in social and cosmic development. Ever since the dawn of conscious thought there has been the contrast

between the eternal and the temporal aspects of things. In their search for some safe ground in the whirl of events the ancients established to their satisfaction a natural unchangeable order of things: day and night, the seasons, the firm land and the regularly moving sky. That realm of the unchangeable was, from Greek days at least, the chief domain of science and the idea that science was discovering the invariable laws of the creator was a guiding thought right down to the days of Newton and beyond. But against this tendency there has been another; the world is full of evidences that its past is not like its present, that the only reason that we take it as unchanging is that changes are too slow for our observation. The study of fossils, the unravelling of the evolutionary family trees of animals and plants by Darwin in the nineteenth century, was a challenge to the idea of an unchanging universe. The range of evolution is now enormously extended; it stretches back to that of the earth, the sun and the cosmos itself. We can see now that the two aspects of regularity and evolution are complementary and universal; the only constant thing is change. It is in the study of changes and how they come about that the larger unification of science and human experience becomes possible. The realisation by Marx and Engels one hundred years ago that the apparently arbitrary political and economic changes of their time were part of a pattern of transformation that had extended over many centuries gave the clue to the understanding of change. It explained how it occurred in alternate stages of gradual and abrupt transformation. This fertile concept of dialectic materialism could be stretched back in time to explain change in the pre-human world, in the organic and even in the inorganic universe, and the wider and deeper understanding and unity that this gives to modern science is discussed in the last group of essays.

The dialectical concept of evolution increases our understanding of the past only to give us a firmer and more conscious grasp of the present and the future; the wider coherence of human experience increasingly expressed in collective action shows that the major feature of the transformation of our time is the coming into existence of a totally conscious phase of human evolution. In the past men have been aware of immediate objectives and in pursuit of those immediate objectives have come into conflict with each other as individuals, as peoples and as classes.

Now those who can see the wider possibilities, through the disciplines of science, natural and dialectical, philosophy can analyse, plan and act for humanity as a whole. To those lacking this vision all that can be seen of the present is the decay of the old order which they equate with civilisation itself; it is a time of dread and despair. But to those who do understand and see a new civilisation being born out of the ruins of the old, it is a time of struggle and hope.

January, 1949 J. D. BERNAL

MAN AND THE WORLD

INTRODUCTION

THE three essays in this section stand somewhat apart from all the others in that they attempt in different ways a general summary of the total reaction to the world situation. All attempt, on different scales, to sum up and analyse the character of the new beliefs that belong to our times as those of Liberalism belonged to the dawning nineteenth century. All are products of the events of the war and in reading them this should be kept in mind. The first and longest, *The Freedom of Necessity*, was begun in 1941, although published somewhat later, just at the turning point of the war when the fate of the world still hung in the balance. It was an attempt to look at the immediate events in their wider context and show the struggle that was then going on as part of a much wider struggle which had begun before and would go on for many years yet. The title expresses the intrinsic character of modern scientific thought that freedom is to be measured by knowledge. In so far as we do not *know*, we also cannot *do*, and any freedom we have is illusory. Many find this a hard saying and equate it with fatalistic determinism, but for those who appreciate the nature of science it becomes increasingly self-evident. Its great value is as a stimulus to deeper and more comprehensive understanding and to an attitude of resolute humility, standing as we do always in ignorance but having greater knowledge and consequently greater responsibilities than our forerunners.

"Belief and Action" was written in a time of more personal expectancy just before D-day in 1944, an attempt to set down briefly and logically the canons of a modern faith, one essentially as humanistic as it is scientific. It is based on man and his capacity through society for unlimited development. This belief is shown to be held not mystically but logically, for mankind, as creators and carriers of civilisation, includes implicitly all the rest of the universe. The relation of man to society which creates him and which he creates sums up all

other relationships and the social responsibility of man takes the place of the older individualist moralities.

The last and shortest essay of this series belongs to the early post-war period and was given as a broadcast in a series "The Challenge of our Time." These broadcasts brought out most sharply the contrast between what were then called the "confident scientists" and the writers, artists and theologians who could only see misery and decadence in the present and worse destruction to come in the future. The challenge of our time, my broadcast contended, was to be met not in lamenting the past but in moving vigorously forward to create a new and more conscious civilisation. Since these essays were written, events have even further deepened the rift between the positive and negative attitudes towards world affairs—between those who are willing, in preserving the old values, to compromise with all forms of reaction even to the extent of war, and those who in the interests of the future are willing to make a break with past traditions and are striving for a popular unity that will make war impossible. The hopes that are expressed in these essays will not be realised as easily as seemed at the time they were written, but they still mark out the path of advance.

THE FREEDOM OF NECESSITY

I

The War

THE war we are now fighting is not only the greatest but the most important war that has ever been fought. It is the most terrible and at the same time the most hopeful of wars. Something is happening in the world now that is altogether new and of a different kind from any happening of the past. We cannot accept the struggles and miseries of today as they have been accepted heretofore. We know too well that they are not the result of blind fate or the vengeance of an offended god. We know even that they are only in part the results of human

folly. Most people, without understanding very deeply what is happening, do sense something different, do see vaguely that behind the raids and battles lie other greater and more enduring changes. They realise that the whole framework of life is altering so much that not only is the world unlike what it was before the war, but that it will never be like that again. This is not merely an English or German or Russian viewpoint; it spreads over the whole of mankind. It is now apparent to all that we are witnessing the end of an age and the beginning of a new one. The change that is occurring is more important than any that has happened for many thousands of years: indeed as far back as history records. One reason for the struggle and confusion is that it is too big a change to be fully grasped, even by the people who are bringing it about. Yet any hope for a speedy and good issue from our present troubles lies precisely in realising what is happening and what is our part in the process.

The Social Transformation

A great social transformation has been maturing in the past four hundred years. For the first time human beings are beginning to control the conditions of their lives—the whole human environment—consciously through the use of science. An enormous mechanical apparatus of material production and distribution is already in being. But it has been built up in the framework of the old civilisation, fundamentally traditional and unscientific, the pillars of which were private property and state authority, and in which the only forms of international relations were trade and war. The gigantic growth of productive powers is now cracking and tearing to pieces this old framework. It has visibly failed to provide, indeed it was intrinsically incapable of providing, for the extent of co-operative planning required for the working of the modern productive machine, and the result of its failure has been a series of ever increasing crises. These have at last broken down into a war which is in itself becoming the main concern of almost the whole population of the world, and is already absorbing more than half its productive capacities. Things cannot and will not go on like this. The realisation of new human possibilities for winning a good life for all is now

reinforced by the knowledge that they are not only possibilities but necessities; they are the only alternatives to increasing poverty, insecurity and death. Men must work all together if they are not to spend their lives and strength killing each other.

Human Unity

The new age is showing a new awareness of the unity of all human societies and of the practical possibility of co-operative human effort in satisfying all their needs. Both unity and co-operation have been made possible directly and indirectly by the growth and application of science. They are due to the increase of communication and economic interdependence and to the world-wide triumph of the industrial revolution. What is new now is not these things themselves so much as the fact that people are becoming consciously aware of them. A hundred years ago Marx and Engels saw them as clearly as we see them today, but they were almost alone then, and their ideas have had to fight for recognition through years when to outside appearances they bore little relation to facts. The nineteenth-century liberals saw nothing odd in looking forward to the steady and eventless evolution of free trade economics in a world where everything was for the best because everyone was seeking his own profit in the most intelligent way. They were proved wrong, by the actual and necessary historical development of liberal capitalism. On one side there was the growth of an organised and potentially revolutionary working class; on the other, the irresistible tendency, in the pursuit of larger and safer profits, towards monopoly, imperialism, fascism and war.

Planned Economy

Today the situation is very different. It takes an effort to accept the old liberal view. Now, in wartime, we are coming naturally to think and act in terms of directed economic and social organisation. The relics of the past are still with us, preventing the adoption of rational solutions to urgent national problems and perverting these solutions everywhere to private ends; but in so far as such interests do interfere, they bring their own destruction. Already national efficiency, which means conscious social organisation, is a condition of national

survival. The fall of France has shown this well enough. In every industrial region of the world today—and non-industrial countries can have no effective say in world affairs—there exists a form of planned economy determining the quantity and quality of production, fixing the movements and the occupations of the population. More and more the capitalist states are showing an external similarity, in their means of control of production and distribution, to the planned socialist economy of the Soviet Union. Insofar as they still fail to equal its achievements even with greater material and technical resources, it is because their economy cannot make a fully integrated plan or liberate the full constructive ability of the working class.

The Need for Conscious Understanding

For most people the consciousness of the meaning of these events is lagging behind the events themselves. Yet that consciousness is not an inert and academic thing; it is a vital and overwhelmingly powerful factor in shaping events. Hitler and his hidden allies among the United Nations know only too well that once that consciousness is general, nothing can prevent the ultimate establishment of a democratically organised—that is, of a socialist—world order. Hence the frantic attempts to build up exclusive and aggressive nationalist feeling in order to prevent the realisation of this wider concept. But there is no room left for a world of independent rival national states. The only apparent alternatives now are world domination by force or world co-operative organisation. In reality there is no alternative, because domination by force is practically impossible, and would not be stable if it were achieved.

Yet although an increasing number of people has realised in their broad essentials what the immediate possibilities are, and although there is an underlying agreement about them which goes far wider than many national and class boundaries, there has been extraordinarily little explicit statement of the nature of the present transformation, or of what is needed to effect it more rapidly and with the least destruction and misery. For many hundreds of years thoughtful men have drawn pictures of good states of society. All these utopias have faithfully reflected both the conscious aspirations and the

unconscious assumptions of the age in which they were written. But what we want now is not a utopia; indeed we know that social transformations are not to be achieved by making blueprints and attempting to copy them in actuality. What we need is an understanding of the processes of the working and transformation of societies, sufficient to enable us to see which things are worth attempting and which are doomed because of the inherent contradictions which they contain. For example, however well balanced the constitution of a state may appear to be on paper, if it is so arranged that one class has a definite advantage over others, that class is bound either to sweep away or to evade its constitutional limitations and to generate among the rest of the population an antagonism that sooner or later comes to revolution or war. Plato's *Republic* or the liberal utopias of the last century were full of contradictions of this kind.

Ideals and Possibility

It is therefore not our first business to set up ideals, though we may recognise that the ideals already embodied in human society represent powerful forces. For instance, although abstract justice is hard to define, the feeling of injustice and the demand for justice can be recognised as great moving forces which will always turn against any deliberately fostered privileges or inequalities. It will be found that by setting out only that which is possible, a great deal of what is recognised as desirable and good must be included. It might be argued that the converse is also true—that by setting up the ideal of what is desirable and good, we create the need which will secure the ends. But this has not proved to be the case. The whole of early Christian effort was towards the establishment of a kingdom of God which would realise the full flowering of human virtue. This attempt was abandoned many hundreds of years ago by the religious themselves, who were driven by the very development of a commercially based society, which they did not understand, to limiting virtue to the conduct of private affairs. The men of the Enlightenment of the eighteenth century struggled for a different ideal: an ideal of liberty in which everyone was secured in the possession of full freedom of political and of economic action in so far as he could pay his way. That ideal came more near to being realised, but the

way of reaching it led past it to monopoly capitalism and the fascist state.

There is still a tendency to begin with the rights, and, rather more rarely, with the duties of the individual, and having set these out, to demand the kind of state that will realise them. This was all very well in the times of the great English and French revolutions, when the assertion of individual rights against feudal status was of paramount importance; but it has no meaning in the modern world where the first problem is to establish a social and economic organisation which can at least provide food and clothing for its citizens and save them from the constant threat of death or slavery. This does not mean that the demand for human rights is abandoned. On the contrary, it means that they can only be secured by first attending to the shape of society as a whole. The Soviet constitution not only guarantees the liberal rights of equality before the law, but also the new rights of employment, of education and of security in illness and in old age; but such a constitution could only be drawn up after the achievement of a socially operated and controlled productive system. The four freedoms of President Roosevelt—Freedom of Speech, Freedom of Worship, Freedom from Want, and Freedom from Fear—have not as yet the same reality, precisely because they lack the economic and political basis that could secure and guarantee them.

The Best Human Environment: Biological and Social

The general object of human society, which can be realised only by our becoming conscious of it, is, in scientific terms, the establishment of the best possible biological and social environment for every man, woman and child. A good biological environment means, for human beings, what for years past it has meant for domestic animals—plenty of good and agreeable food, freedom from excessive heat or cold, a pleasant atmosphere to work and play in, security from the attack of all avoidable diseases, and medical treatment for all unavoidable ones. All these things are the common human birthright, and, owing to the war, they are beginning to be generally recognised as such. That all men should have to fight for food, that some men should starve, that children should grow up stunted and diseased, that conditions of work

should make that work a misery, that old age should be passed in pinched anxiety, are now seen not only as avoidable evils but also as intolerable handicaps to an effective social life. To put it in its lowest terms, a country which allows such conditions cannot be making full use of its manpower. Any farmer who treated his animals so would be working to his own loss. But once this is admitted as a human birthright, all the compulsive sanctions of capitalist economy fall away. In a socialist state new sanctions take their place. Work is a social responsibility. The right to work and the right to good living and working conditions imply the obligation to work.

The securing of the best biological environment is only half the story. The social environment is in fact more immediately important than the physical one. Unless a man is starving, freezing, ill or wounded—and often even then—he is more affected by how he stands with other people than by his physical sufferings. To have a place in society and be recognised and approved, to feel that one's work is valued, to be able to enjoy companionship, to have a sense of security in family relationships and respect in old age, are actual necessities more keenly felt than most physical ones. A sense of grievance or inferiority, a lack of hope for oneself or one's children, are social conditions as destroying as most diseases. Good social environment implies the absence of such evils; but it implies more. It implies a positive consciousness in all men and women of working together for the common good, so that each sees his reward in his fellows' approbation. It implies further a fundamental combination of freedom and co-operation. Everyone must feel that he is playing a part in a common human enterprise, a part that he can and will play to the best of his abilities, and for which he is essential in his own way. At present we tend to think that freedom and co-operation are incompatible things. Individual freedom seems to stand always in opposition to the state. The answer lies not in trying to decide the issue between anarchy and order, but in revising our organisation of the state and our education of the individual.

The Productive Mechanism

Good biological and social environments for human beings cannot be achieved piecemeal. Generations of reformers have

attempted to do this, but while they dealt rather ineffectively with the details—providing public parks and hospitals—they left untouched the major factors that drove towards unemployment, wars and mass misery. The only way of securing a good environment is by setting up a well organised productive and distributive mechanism. Good biological and social environments are not separate things. The biological environment is secured through human work with the assistance of the knowledge given by science and the powers given by machinery. The conditions of work are the essential feature of the social environment: not only how people work in a material sense, but how they are organised to work and what they think or know they are working for. The part that people play in the productive mechanism will for a long time determine the quality of their social relations. Conversely, the very functioning of the productive apparatus, what and how much is produced, how it is produced and where it goes, depends on the form of social relationships. It is not for technical reasons, for example, that more than half of man's labour is wasted by unemployment in peace and in killing or preparing to kill other men in war. It is useless to increase productive efficiency or improve means of transport if the social control is so organised that it can only lead to such results. Any productive organisation that will not lead to such results, in other words, any steadily progressive, productive organisation, implies certain social conditions.

Productive Organisation

The setting up of a working productive organisation, consciously directed to the satisfaction of human needs, is the primary social aim of this time. It implies first the negative work of crushing all social forces that tend to check the development of the new productive forces or to divert them to destructive or limited ends. On the positive side it implies the actual planning and putting into operation of a vast interrelated set of schemes for raising human productivity to new levels, and for directing that productivity at every stage so as to satisfy human needs and enlarge human capacities. At one time the negative aspect will be the more important one, at another the positive. Thus, from 1917 to 1923 the forces of socialism in the

Soviet Union were mainly concerned in defending their newly won power against internal and external attack. Then from 1927 to June 1941 the main emphasis was on planned reconstruction of the physical and cultural standards of living. Now once again it is the negative aspect that predominates. The Nazis and all they stand for must be crushed, but in the midst of warfare the achievements of the constructive phase are still essential.

Human Needs

It is far easier to aim at satisfying biological than sociological ends. We can formulate fairly accurately what the basic biological human needs are, and the steps that need to be taken to satisfy them. We have not yet reached a sufficiently advanced state of knowledge to assess accurately the social needs; but we do know enough to realise that social needs will best be satisfied in the very effort of achieving the biological ones, not only because social welfare implies an adequate biological environment, but even more because experience has shown that the very effort to obtain this environment by social collaboration results in the satisfaction of the most fundamental social needs. Society is always at its best when the people who compose it are working for a common recognised end, which enables them to collaborate and to subordinate their individual aims in an atmosphere of social approval. Except in socialist countries, only war can bring out this conscious social unity in action; and it is remarkable how easy then it is psychologically to sweep away minor private interests for the sake of common welfare and how major private interests which continue to stand out against this process are becoming increasingly discredited and insecure. A common purpose has its immediate emotional effect on every individual, but that purpose can only be realised in common organised action—that is, by effective democracy.

Democracy

Under present-day conditions, no great enterprise can be carried out to ultimate success unless it has the willing and conscious collaboration of hundreds of groups of human beings working in different capacities. Even in Nazi Germany, an elaborate and costly propaganda apparatus is required to

persuade the people falsely that they are working in this way; and the fact that that deception is becoming suspected inside the country is one of the most significant signs of the breakdown of fascist regimes. Now the technique of working together in small groups, for purposes which extend very much further than those of the individual members or of the group itself, is, rather than the ballot box or the party system, the essence of democracy. The difference between the new and the earlier attempts at democracy is firstly, that it is a truer democracy in that it does not depend for its existence on classes of slaves, machinery having supplied that deficit; and, secondly, that it recognises that each democratic group exists and works only by virtue of belonging to a larger scheme containing many thousands of such groups, co-ordinated in a planned way for a common purpose. The practical possibility of planned and organised production for the common good was first realised on an adequate scale in the Soviet Union. Its technical possibility throughout the world has been brought far nearer by the present war, which has forced every other large country to imitate many of its organisational methods although they are hampered in their effectiveness by existence of the vested interests of nineteenth-century capitalism.

Use of Natural Resources

No one who has ever considered the matter would now doubt that given the political conditions it would be perfectly feasible to set up and get working within a few months a comprehensive productive and distributing mechanism for the whole world. The technical side of this has already been demonstrated in practice, but the possibilities go far beyond anything that has yet been achieved. By throwing the whole weight of scientific inquiry into the problems, it should certainly be possible to increase vastly the relevant usable natural resources of power and materials. The basic requirements—food, working materials and energy—are potentially available in quantities far in excess of present needs, and indeed of the needs of a population many times as great as the present one. Pessimistic critics of the last fifty years have continually harped on the limiting of natural resources and the danger of exhausting them if they continue to be used or wasted at the present rate. These critics have been

refuted by events, as new sources have been found and new means of conserving and economising existing ones have come forward more rapidly than the possibility of using them under the increasing restrictions of capitalist economics. In the past few years it is the problem of surplus rather than the problem of exhaustion that has become most prominent, and received the immediate and utterly foolish solution of restriction in peace and arch-destruction in war. But the development of science has shown that we have found greater resources than those that can be measured in millions of tons of coal deposits or millions of kilowatt-hours of water-power. These resources lie in the methods and achieved results of science itself, in the vastly increased possibilities brought about by the expansion of scientific method in the practical field. We are, for example, on the eve of a transformation of energy sources which, by using atomic energy, will make the whole world independent of further coal or oil supplies. We can now see how to do things in such a way that natural resources such as working materials or food do not vanish irrecoverably, but go through a controlled cycle of use, scrapping, regeneration and re-use. The real resources of humanity are intellectual and social rather than material. If society can be organised so as to use its intellectual resources to the full, it need not fear material scarcity.

The Economic Problem

It is the social problem, therefore, rather than the technical one, that is critically important. Man must learn how to collaborate effectively before his material and intellectual resources can be used to produce happiness instead of misery, peace instead of war. Shallow critics have urged that the failure to achieve this is something intrinsically human, that man's social and moral sense is incapable of dealing with the problems of a mathematical and scientific age. They draw from this easy reflection the conclusion that it is necessary to return to a simpler age. Plainly, this is not happening nor likely to happen; in fact there are many good and detailed reasons for our present troubles which have nothing to do with man's inherent wickedness. We have, in the first place, inherited from the preceding era the social form of private appropriation of the results of social labour. A hundred years

ago Marx, practically alone among his contemporaries, was brilliant enough to see that this was bound to result in just that distortion of productive effort that we are suffering from today. We have now had ample evidence that it is impossible with modern technique to get a well-running productive and distributive mechanism operated entirely by the condition that it should furnish profit and interest to individuals contributing little or nothing to its direction or maintenance. Their greed and stupidity have only brought increased human misery without even saving their wealth or themselves in the process. These conditions are not accidental, they are the recognised basis of the economic system. Greed or stupidity would be called, in official, financial, or academic circles, commercial good sense and strict attention to business. There is no place in any modern social structure for such attitudes, or for the people who have inherited them with their wealth and arbitrary power.

Planning

The new consciousness of the unity of human society takes practical form in economic planning. Planning in this sense is the antithesis of the free market which was the ideal of the classical capital economists. At first sight it does not appear so different from the state- and monopoly-controlled economic organisation of the present day. All the advantages claimed by the economist for the free market have already practically disappeared. But most of its disadvantages remain, and in addition there are many new ones characteristic of monopoly—restriction, high prices, lack of adaptability. But the planning in monopoly state capitalism, whether fascist or plutocratic, is not a corporate attempt to obtain the best possible human conditions with the available resources. The planning that will achieve this is fundamentally different. In the first place it needs to be complete, for no plan for any individual sector or for any number of sectors is likely to achieve good results if the plans for the different sectors do not form part of one whole. The gross failures in war production and in the provision of food and necessities in this country have shown that well enough.

In the second place the plan must be socially controlled and must not attempt to protect every individual interest which

enters on the productive side. Even if the whole of industrial and agricultural production in this country were co-ordinated it would be impossible to achieve anything but further restriction if the profits of each separate group have to be guaranteed. The situation of the transport system in this country which was rationalised in such a way as to preserve the vested interests of obsolete railway companies is an example of this. If the resources of modern technique are effectively used, it is certain that much old machinery must be scrapped and many workers in old trades will have to learn new ones. Such scrapping is really feared now because of the insecurity of the worker in our present society. It would only be accepted and welcomed under social control directed towards the general welfare of all workers.

Thirdly, no plan can be effective if it is not scientifically conceived. The attempt to use existing techniques in their present relations to each other, even if economic restrictions were removed, is bound to be grossly inefficient. The present relations of the different parts of production have grown up to satisfy the profit needs of separate interests; it is certain that they do not represent the best way of using existing resources for the benefit of the community. To find out how to do this is a scientific problem of great complexity, but it can and must be solved. The last defence of the classical economist is the claim that, bad as the system of the free market is, it does enable production to be carried on without any need to think out how much of each commodity should be produced and where and when it shall be required. This they consider an absolutely impossible task. For the past ten years, however, it has been regularly solved in the U.S.S.R., and similar tasks are being faced in wartime England, Germany and the United States. The technique exists for answering such questions by the use of statistical methods and simple calculus of variations, and practice will soon perfect it. It would be very odd if groups of intelligent people, having available to them the combined wisdom and experience of past generations, could not, by working consciously, achieve better results than were obtained by the uncoordinated, half-conscious guesses prompted by the greed or fear of business men lacking special training and ignorant of most of the relevant factors.

Finally, and most important of all, no plan and no produc-

tive organisation will succeed in its object unless it has behind it the organised and conscious will and desire of the workers. As the productive machine grows in size and complexity in the latter stages of capitalist development, the workers in it gain in cohesion with their increase in numbers. This is particularly so in war. The workers and technicians between them come to realise that it is their show in fact, however it is owned and controlled. They work it, they understand it; the others only exploit and obstruct it. The workers are the people for whose benefit the whole machine is working, or should be working. How they work, and why they work; is as important as what they produce.

The Meaning of Human Rights

The effectiveness of the productive machine depends on social no less than technical factors. It would be of little value unless men and women could work and charge it willingly, freely and consciously. Political forms and social customs must make this possible.

In the past these were not often thought of as the establishment of human rights. The ideals for which the great struggles of the last three hundred years have been fought were summed up in the three great rights of man of the French Revolution—liberty, equality, fraternity. They were then claimed as absolutes. Now they appear relative to the technical and political movements of the time. Interpreted in the light of the present, they may still stand as necessary conditions for an effective productive mechanism, and, at one remove, for the provision of a good biological and sociological environment. But, though rights are conditions, their winning is not to be thought of as prior to the establishment of the productive organisation. Rather do they arise out of the struggle for achieving it.

Equality

For us today human equality is no longer a dogmatic assertion that all men are born equal. We know that this is not so, either in physical or in mental endowment. Nevertheless, the men who fought for equality were fighting for something real against arbitrarily imposed inequality. If equality is considered in relation to social or productive organisation,

it is seen to mean that only man's functional capacity—how good he is at his job—should determine what place he takes in the general productive scheme. To bring in other considerations, such as colour, religion or relationship to a director, is to lower fatally the efficiency of the organisation, firstly because it means that full use is not being made of human abilities, and secondly, because the knowledge of this gives rise to a feeling of injustice, which makes it absolutely impossible to secure the full voluntary collaboration of all workers. Every man doing his best in his own job is on that account the equal of any other.

If everyone's place is to be determined by his ability, it should clearly be determined as early as possible in order to make the fullest use of his potential ability. Equality therefore implies equal opportunities for education in the full sense, including the abolition of special advantages due to social status of the parents. The two forms of society that preceded the present were essentially based on the exploitation of arbitrarily created inequality: in feudal society by status, in capitalist society by wealth. Capitalist society was more progressive, because, though status could not be changed, wealth could be acquired. Nevertheless, by putting the making of money, and therefore the getting of an unequal status, as its main objective, it was bound to give rise to a far greater inequality than the society it superseded. By bringing the world within one commercial orbit it indeed introduced entirely new inequalities based on race, or more accurately, on the relative degree of technical development which existed at the beginning of the industrial revolution. Racial inequality is the clearest example of the inefficient utilisation of human ability. This is even consciously expressed by the colour-bar laws of South Africa, which prohibit the natives from carrying out tasks which at the same time they are alleged to be inherently incapable of undertaking. Racial inequality, further, brings its own nemesis in shrunken markets, fear of insurrection, and imperialist wars.

Another form of inequality which must be removed is that between the sexes. Once effectiveness in function is accepted as the test this happens inevitably, as is shown in the war. Equal educational opportunities, equal pay for equal work, will not prevent women and men tending to do different things; and

the production and care of children is sure to claim much of the life of most women. But these will be voluntarily accepted conditions, not imposed by a society which has outgrown the full-time domestic occupation of women and which is ridden with the fear of unemployment. Race and sex inequalities must go.

The society of the future cannot admit any type of imposed inequality, because in doing so it would defeat its own ends, the achievement of a good environment by efficient productive organisation.

Liberty

Liberty is usually put forward as a purely negative social concept. It implies that men have been, or usually are, subject to conscious compulsions, whether by owners, employers or governments. The establishment of liberty means the removal of these compulsions. From then on they are free: they can do what they like. This definition goes too far and not far enough. Besides the conscious compulsions enforced by chains, whips and starvation—or the fear of these—there are unconscious compulsions which can be built into the individual's character by his social environment. These compulsions can make men, apparently of their own accord, a nation of slaves or a gang of tyrants. But liberation from all social compulsions, conscious or unconscious, is intrinsically neither desirable nor possible. Men cannot escape from society, and when they appear to do so, the resulting perversion of social values is often disastrous. Thus in the early days of capitalism, liberty meant freedom to do what one liked with one's own. But the liberty of the trader or manufacturer meant the enslavement of the worker in the plantation or the factory. Usually this difficulty in the definition of freedom is evaded by demanding that men should be free except in so far as their actions injure other people. But, apart from such obvious and unimportant examples as common assault, it is extremely difficult in practice to tell how by doing or not doing a given action one injures other people. Those responsible for building the industrial towns of the nineteenth century, for example, were injuring millions of people for many generations without any consciousness of doing so.

But even this questionable liberty of the nineteenth-century bourgeois is no longer with us today. We see in country after

country the violent destruction of liberty, the open enslavement of whole peoples. The dictators who do this are merely symptoms. They would have no power if the bases of liberty had not already been undermined by the growth of monopoly and the disappearance of the independent economic man. The sanctions that secured that liberty for men of property in the English, American and French revolutions have gone. The new liberty must be for all, but it will be a different kind of liberty.

We would now consider liberty in a much more positive aspect: freedom to choose in what manner man can best fit in with the general social activity. He cannot evade some part in that activity, even if he feels antisocial or is parasitic on society; nor can he entirely determine what his part should be, for this depends on his abilities and the opportunities actually present in society. But within these limitations the choice should be his. The more a man understands how society works, the more he understands what he can do easily and well and what he will muddle and fail at, the more scope there is for his activity and initiative, and thus the more is he a free man. Freedom in a modern organised world is bound to be different from freedom in the ancient world which simply meant the absence of slavery or serfdom: or freedom in the early capitalist world which only meant absence of restriction on profit-making. It will be an ordered and not anarchic freedom, but there will be room to choose one's place or to make a place for oneself.

No society which does not make fullest allowance for individual initiative can be productively efficient. But the way of securing that initiative must necessarily be different from what it has been in capitalist society. It must work corporatively, not individually. The initiative for change must come from the individual, but the change itself must be social and agreed on, and therefore it will be the business of the individual to persuade his fellows that the change is necessary. Actually the new society is bound to be one in which rapid changes and developments are continually taking place, and the scope for initiative will be very wide. There is no doubt that within the last few years far more initiative and imagination have been shown in social and productive development in the Soviet Union than in any of the countries of free capitalism. Liberty

in the new world will come to mean the social acceptance of the fullest use of the capacities of every individual.

Fraternity

Fraternity has a strange sound in these days, and yet it is the most important of the three rights because from it the others follow. In spite of the fact that the world is now involved in the greatest and most bloody war in all its history—or rather, almost because of this—the feeling of common humanity and of the unity of human beings all over the world has never before been so strongly felt. There is little real hatred now between peoples or races, only between oppressors and oppressed. Fraternity is now felt as world-wide, owing to the immediate way in which events in one part of the world affect all others. The Spaniards and the Chinese, early victims of fascist aggression, were not unaware of each other's sufferings or of the way in which their fates were linked. The only barriers to fraternity are those implicit in earlier social systems, greed and fear arising out of conditions of exploitation. Those who knew they were getting more than their share of the world's goods feared and consequently hated their victims. National states, when they assumed the importance of monopolist industrial groups, were driven to use every device of propaganda to create national and racial antipathies between their masses of exploited subjects and those of other national states. These real and artificial hatreds have been sufficient to maintain the world in a state of insecurity and warfare for the past fifty years or more. But, paradoxically enough, it is the intensity of war itself that is likely to break them down. Common men are common victims to a situation and as they find this out their mutual antagonisms will turn into a common determination to have done with the system that can offer them nothing better.

In a new world the driving force behind the whole productive and social organisation will be the feeling of common fraternity. It is no use having an ideal system, technically and mechanically perfect, if behind it there is not a human emotional drive. In the past that drive has been the greed of the owners and the fear of the workers, but this cannot remain so. Those sanctions are wearing themselves out in

the present chaos. A new drive must be common and voluntary. Sooner or later the communist slogan, "From each according to his ability, to each according to his need," must be realised in practice, not because this is an ideal but because it is the only way in which a productive mechanism will ever work satisfactorily. Naturally this cannot come about at once. In the social conditioning which has affected every member of present-day society, the feelings of fraternity have been limited firstly to a narrow family circle and secondly to small social groups—the trade union and sports club and old school. Not many capitalists, even in the heyday of capitalism, worked only for themselves; most worked for their families or occasionally even for the investors in their company. To widen effective fraternity, to make people work for a larger group which ultimately embraces all humanity, is an educational task which will take at least a generation or two. But it is not the education of the schools. It is the education of the experience of life itself, of the impact on people, often for the first time, of events in the outside world coming to them through the restrictions, the efforts and the miseries of war. People begin to see that we dare not risk prolonging for ever a conflict between private and public interests and that the two can come together only through a well-organised society. Fraternity is not an ideal virtue to be obtained in the distant future. It is a practical necessity for working together now to make a tolerable world.

Liberty, equality and fraternity are more than human rights: they are necessities for human survival. When the French revolutionaries cried "Liberté, Egalité, Fraternité, ou la Mort," they were expressing a fact as definite as the open threat. In the present state of the world, with the new potentialities that man has acquired for himself, any infringement of these rights brings its own consequences in human misery, social disorganisation and war. But human rights cannot be secured without the creation of effective productive and social organisation. The winning of rights, or the safeguarding of rights already won, is now seen to be not merely a political act, but an economic and technical one as well. Without securing the basic biological and social environment, these rights become empty words. That they were not always so in the past is because then men could still rely on the modes of social and economic life inherited from the ancient world.

They could still take such things as agriculture, handicrafts and trade completely for granted as the natural state of man. We can do so no longer. The mechanism of production and distribution has been transformed by a combination of technical and scientific advances. There is now no safe and stable basis for society. We must, for very life, understand and control its economic and political form.

II

The Transformation in Ideas

The achieving of a rational social economy is the central necessity for men today. It is the next step in human evolution. But because any successful solution must now be a conscious one, conscious understanding must pave the way to its achievement. This understanding must extend beyond the immediate political and economic problems. It must penetrate deeply into their origin and form an intelligible and dependable basis for construction as well as revolution. The great transformations of history have always been accompanied by the building of a new picture of the relation of man to his universe, bringing with it a change in values and methods of thought. Such intellectual formulations do not, of course, cause the political and economic changes, but they do provide its conscious expression, particularly in the minds of those who are most active in bringing the changes about.

The set of ideas which we take over from past generations inevitably includes a profound acceptance of the old state of things. The values which go with these ideas are values suited to the economy of the old society and will not serve for making a new one or for living in it. New ideas and new values have, however, been growing up and are now almost ready to appear as the directive forces of larger transformations. They have come into being and have spread because of the moral and intellectual decay produced by the breakdown of the old regime. Although they can be traced philosophically as far back into the past as we wish, they were first enunciated effectively in the heyday of capitalism in mid-nineteenth century Europe by Marx and Engels.

Marxism

Ever since the appearance of the Communist Manifesto in 1848 there has been what might be called a permanent opposition to the once universally recognised liberal-capitalist picture of the world. For many years this opposition was confined to active working-class circles and to a few eccentric intellectuals who from time to time came into touch with them. Official intellectual circles did not so much attack these ideas as refuse to recognise their very existence. Marxist economics, Marxist history, the contributions of Marxism to philosophy, natural science, and the arts were usually excluded from mention in universities and learned books. Even when political Marxism became powerful, as, for example, among the pre-war Social Democrats in Germany, Marxist thought was shed along with revolutionary politics. Nevertheless, a considerable infiltration of Marxist ideas into general thought was consciously or unconsciously taking place. With the advance of science it spread into wider and wider fields of human affairs and led to the discarding of many ancient superstitions. It was, however, the success of the Russian Revolution of 1917, and perhaps even more the first five-year plan of 1928, that gave the first visible evidence to the world outside Russia of the existence and significance of Marxist methods. Marxism might be more feared and hated than before, but it could no longer be ignored.

The great new developments of science of the early twentieth century, with their emphasis on the unity of all the sciences, led almost inevitably in the learned world to a readier understanding and acceptance of Marxist dialectic. If in the Soviet Union great things could be attempted and achieved, while in the capitalist world there was nothing but depression, want and fear of war, there must be something in the ideas behind the Soviet Union that was lacking in the traditional ways of thinking. These events led not only to an increasing study, acceptance and enlargement of Marxist ideas, but also to the unacknowledged borrowing and absorption in the accepted views of the age. The importance of the economic factors in history, which were still ignored or denied at the beginning of the century, was by 1940 becoming a commonplace.

The transformation of ideas has been working quietly and

steadily. Already everything new and vital in thought lies along these lines. The time is almost ripe for an open reformulation of beliefs and attitudes to the world, comparable with, but far greater in scope than, those that marked the acceptance of Christianity or the Protestant Reformation. The difficulty of bringing about this change is, however, still very real, particularly in countries where all social and economic forms still belong to the old order even where they are in most obvious decay and disintegration. It is made even more difficult by the absence of any clear and comprehensive statement of what the new way is. The times we live in have been so full of great events, and the need for action among the conscious few has been so urgent, that we have not had anywhere a full statement of what we believe and are driving at.

New Beliefs, New Aspirations

Treated at large, of course, this would require not a book but an encyclopaedia, and a far fuller one than the great French encyclopaedia that ushered in the world of liberal capitalism. But it need not be treated in full to bring out the essential features whereby the new ideas differ from the old. Everyone has enough particular experience to see where and how the general theses need to be expanded to meet his fields of knowledge and action.

The essence of the change is that we no longer believe that we live in a stable and unchanging world constructed and maintained by invisible and mysterious forces or gods, and that all we can do is to seek by ambition and industry to achieve success and pleasure in this world, and by virtue and abnegation to prepare for a better world hereafter. Instead, we see the universe as a process of change and transformation in which new orders—stars, planets, life, animals, and finally ourselves in human society—arise one after another, not in accordance with any foreordained plan, but because of the internal strivings and contradictions which bring forth the new from the old. We see these struggles around us in human society here and now, and we see, moreover, that their outcome in building up a new stage of consciously world-organised society depends on our actions. With this understanding, man becomes for the first time a full master of his environment,

social as well as material. It is now, as Engels said, that human history begins.

Religion, Change and Science

The new view implies deep moral and emotional changes as well as intellectual ones. Mankind has been sustained for ages through fears, struggles and hardships by a series of beliefs which were ultimately the same, in that they all implied that the affairs of human beings were manipulated by outside forces, good or bad. Men could seek comfort in the love of God and in the belief in an after-life; or they could acquiesce in failure, either because God willed it or because they had been thwarted by malignant forces. These ideas, even though explicitly false, concealed an emotional reality. The belief in gods or God was really the feeling of support from the one eternal thing, the family or kin or society from which we are sprung, in which we live, and to whose future we contribute. Strictly, the savage appreciation of sacred things is far more sound than that of the religious apologist in a modern industrial community. Nevertheless, the whole of this set of ideas, however satisfying emotionally, was essentially static in its implications. The forms of human society were accepted as divine and eternal. Change was impious.

So long as society can be maintained approximately static, such ideas are possible and even necessary, because they sanctify and preserve its technical and economic organisation. They have shown their inadequacy in the long run, only because it proved impossible to prevent change in society. The rise of science, itself a product of economic development, spelt the death of the earlier ideas, not only by criticising and undermining them as statements of fact, but even more by changing the whole pattern of life so that the older ideas had no relevance.

But what is to take their place? One of the first results of realising the possibilities of large-scale modern enterprise has been the abandonment of the restrictive side of the old views with their emphasis on moderation and humanity, without abandoning the positive side—the seeking of individual gain at another's expense. In this sense the Nazi new order is only half-new. It retains the vices inherent in the old system, without its virtues. Fascism can produce nothing but destruc-

tion and slavery. In a really new order all the older ideas will be transformed.

This is no longer a matter of choice: it is matter of necessity. We could not go back to the old ways even if we would; and only a philosophy that recognises both the necessity for continual change and the human responsibility for directing it can lead to a steady and happy progress. If we do not see the signs of this progress very clearly at the moment, it is because we are living in the middle of the transformation itself, and it is unfortunately inevitable that such a stupendous change in human attitudes and ways of life should be accompanied by a wide-scale return to violence and brutality. Out of this violence, however, the signs of the new way are already appearing. Men are finding in the loyalty engendered by the struggles of today an evidence of fellowship and a support far more real than that of religion or philosophy. For both have been undermined for centuries by the more or less conscious hypocrisy which was needed to make them fit with an unjust class-society. The new feeling of human solidarity which now links four-fifths of the world together in the struggle of the United Nations against fascism is one capable of being based on a rational understanding of the world men and women are living in and making, for the new ideas are essentially dynamic and suitable for a changing society.

The New Philosophy

The intellectual changes required for this understanding are at least as deep as and probably more difficult than the emotional readjustments. They affect not only a small and exclusive class of intellectuals, but every human being. Men must think out a reasonable and working scheme of the world they live in and cast away many apparently obvious and long-accepted beliefs. The whole vast body of human knowledge accumulated slowly through the ages, and with embarrassing rapidity in the last century or two, needs to be worked over and revalued as the basis for the new society. This revaluation is long overdue. True, academically we are probably further from a comprehensive view of the world than people at any other time in history. This has always been said to be due to the fact that learning has become too vast for any one mind to comprehend

it. The honest reason is that any attempt to put the whole of knowledge together in a rational way would inevitably mean such a criticism of the existing state of society that it could hardly be expected to find the support of schools and colleges founded to preserve and perpetuate that state of society. Once rid of these vested interests in ignorance, it is perfectly possible at any time to provide a general picture. It will be necessarily provisional because knowledge always grows, not only by adding to itself, but also by criticising and altering its foundations; but at every stage such a picture can and must be the only effective base of action at that time.

Revaluation of Knowledge

The revaluation of present knowledge must be thorough. Our present opinions date from many different periods in human history and, inevitably, the most important opinions date from the earliest periods. We would not accept the ideas of Mesopotamian herdsmen or farmers in aeroplane designing or the quantum theory, but they are still the official basis for family relations and the management of public affairs. In revaluing knowledge we can give no weight to the sacredness of long-established traditions; in fact, these need the most careful criticism. Nor can we rely any more, as the thinkers of the Renaissance thought they could, on intuitive or *a priori* knowledge. The things we are naturally most certain of are simply things that we have learnt so early in life, in accordance with the tradition of human upbringing, that we have forgotten having learnt them. There are no absolute ethics, morals or metaphysics. What pass for these are the many-times-transformed customs of actual human societies. Even logic cannot be accepted uncritically.

Our new grasp of the universe is that of an orderly process, which we learn to understand and control in the same measure. We have now a fairly comprehensive outline picture of how the world is made up and how it develops. We have as well a growing understanding of the mechanisms which lie behind the different appearances of the picture; we are learning the working rules of the universe. These two aspects which, to use old terms, might be called the histories and the laws of the universe, are no longer separate for us as they were for our an-

cestors. To them the appearance of the world—the sun, moon and stars, seasons, animals, plants, birth and death, sowing and harvest—were eternal things to be learned and fitted into life, at best with the acceptance of natural piety. The laws were the laws of God or of nature, as unchangeable as the world in which they acted.

This was, of course, only one half of the story. To explain how things came to be as they were, myth was called in. The world had to begin with a mystical act of creation and to end in a general destruction. But these first and last things were always clearly separated off from the affairs of practical life; they belonged to the other world of time, just as the other world of space contained its heaven and hell. For us today, the history of the world and the laws of its development are part of the same thing, to be understood in relation to each other. We know now that it is only the shortness of our memory and experience that make the world that we live in appear changeless; we know it has been very different and will be more different still. The idea of evolution, apart from any mechanism to explain it, is fundamental to modern thought. But there are implications in evolution that go far beyond the acceptance of progressive change. The very stuff of the universe, the substances and objects that it contains, have full significance only in connection with their part in the process of evolution. It is here that dialectical materialism parts company alike with a simple materialism that takes objects as given and with an idealism that deals only with processes with no material basis.

Every distinguishable part of the world—a river, a tree or a society—has its own laws and ways of behaviour. These laws conform to the underlying material structure, but it is no mystery that this should be so, for if they did not, that part of the universe—that river, tree or society—would not have come into existence and could not continue to exist. In fact, the laws of behaviour and the things themselves are inseparably attached together. The existence of things and the movement of things are one.

Structure and Origin

These existences are not given or arbitrary; they are parts of one manifold process. Each phenomenon or organism has its forms and behaviour because of the event or events in which

that form or behaviour first arose from different forms and different behaviours. There was a time when there were no rivers, no trees and no societies: a time when these first appeared, and the character of that first appearance remains embedded in existing structure. The river and its valley are part of geological history, as well as a part of present geography or present power development. The tree carries in its different parts, leaves and wood and root, flower and fruit, the history of various shifts to which its successive ancestors were put in overcoming physical or biological difficulties in the course of their evolutionary history. So also society in its customs, rituals or sanctions returns, sometimes consciously and sometimes in myth, to its original foundation. In any account of the world, this correlation of structure and historic event is the main modern contribution. It adds enormously to the meaning of the universe because it enables us to give proper weight to the importance of its different parts.

We are not impressed, as were our savage forefathers, by the mere size of the earth and heavens, or by the strength of natural forces, because we know that these belong to a very early order of evolution, that their size and strength go with an organisation almost infinitely simpler than that of the lowest living speck. This, for our generation, is not merely belief but practice. The blind forces of nature are now our slaves. We reserve our real fears and our real efforts for the forces of the most complex parts of the universe, human societies themselves.

The evolutionary process gave us a time chart of the world. We can now see this time chart running parallel, and connected at each level, with an organisation chart. Each stage in the development has its own laws which pass on with it into the subsequent stage, and to them are added new laws which can have meaning only for the more complex and later stages. Priority in time goes with basic simplicity in structure, and sequence in time with the hierarchy of complexity in organisation. It is from this point of view that we can present a full and comprehensive picture of a moving and developing universe.

The indefinite complexity of the actual world, and the fact that we are still only beginning to understand it in detail, should not prevent us from being able to seize the broad

essentials of its structure and history. Almost certainly in the future we may wish to add on important stages that are at present obscure to us, particularly at the beginning of the story; and as human society itself develops, we may ourselves make new stages to add to the end. But the stages we can map out now will still remain.

Critical Stages

The main stages correspond to a series of critical events between which development was comparatively uniform and progressive. They are the origins of the cosmos, with its stars and planets, the origin of life, the origin of human society, of civilisation and of the common conscious control of it. The fact that each of these stages took many thousand times as long as the one following it does not prevent them from representing a true sequence scale of the universe, because it is a measure of not only the number, but also of the complexity of events; and the complexity of the last ten years of the modern social world is greater than the complexity of all the nebulae, stars and planets before the origin of life on any of them.

Going with each of these stages is a corresponding set of modes of motion, or laws. To the origin and formation of the cosmos belongs physics; to the origin of life, chemistry; to the development and function of life forms, biology; to the origin of human society, anthropology and psychology; to the origin of civilisation, technics, politics and economics; to the origin of a deliberately controlled political and economic organisation, the new philosophies of science and society.

What is asserted here is twofold: that we cannot understand or control the historical processes without knowing their laws, and conversely, that we cannot fully understand or apply the laws of science without relating them to the state of events in which those laws first appeared. For example, the study of the chemical structure and chemical metabolism of the simplest living elements in cells is at the same time the study of the origin of life on this planet. The particular chemicals and interactions that occur in cells are not just arbitrarily governed. Biological chemistry seems peculiar because the actual chemicals that occur in animals and plants are an extremely limited set out of the many billion compounds that could be made

from the same number of the same atoms, nor is it easy to see why these chemicals and not others occur. This peculiarity, however, points to the common origin of all biological systems, and to the logically connected sequence of events by which each chemical came to play its new and special role. It does not matter if at present some of the details of this sequence can only be somewhat wildly guessed at. From the pieces that we know already, the connection between origin and behaviour is clearly apparent.

The Origin of Novelty

But to describe the universe, and to explain how it works and how it is evolved, is not enough. To understand and to control it fully, we must know more as to why each stage at its particular time and place gave birth to the next. This problem of the origin of novelty is the central problem of philosophy, and needs to be sharply distinguished from merely verbal problems of the nature of truth or the origin of knowledge. How, in fact, did the new complexities, the new order of existence, the galaxies, stars, planets, life, human society, civilisation, science, come into being from the old? We can no longer do like our forefathers and pretend to answer the question by saying that the new arose through the agency of some mysterious creator or even more mysterious creative force. To us these are mere words concealing blank ignorance, and for us the open admission of ignorance is the beginning of knowledge, for it is the admission that a problem exists to be solved, and a challenge to solve it.

Thanks largely to Marx and Engels we are beginning to see something of the solution to the problem of novelty. We see that no stage is really static, or merely moving round in endless identical cycles. Day and night, spring and autumn, generation succeeding generation or dynasty after dynasty are no longer bounds of our mental horizons. For us there is no longer "nothing new under the sun." Each radical change from one stage of organisation to another is, as Marx saw, a result of struggle between forces which had come into existence in the earlier stage. This is no matter for philosophic speculation, it is an observable fact. In any system large enough and long-lived enough not to be at the mercy of external

forces, what the scientists call chance variations or side reactions are always taking place. These never completely cancel each other out, and there results an accumulation which sooner or later provides a trend in a different direction from that of the original system. In time, the accumulation or trend oversteps the limit of stability laid down in the earlier system; there is a crisis, and, although many crises may be abortive, sooner or later one will introduce a new system with its new order. How this happens in detail is a matter for never-ending scientific research, but we have enough examples of it roughly worked out to see how to present a convenient working account of what has actually happened and what is happening now.

The working account is itself a product of human activities. As time goes on and knowledge accumulates and interests change, new aspects come into prominence—not so much aspects which have been obscure before, as those which have been taken for granted because of our confusion of the familiar with the understood. Thus, in early ages, when the extremely complex organisation of society with its hundreds of customs and traditions was taken for granted, the practical properties of materials were the source both of new techniques and of elementary philosophy. Man has approached simple things first, not only because these are simple and can be seen and understood more easily, but also because they are more removed from the complex of feelings and traditions that build up society. Even today, while we are completely scientific about such things as engines and wireless sets, biology still has to fight traces of old religious views, and economics and sociology have hardly broken away from the taboos against questioning the society in which we live. This reluctance explains how it was that man for so long failed to see the generation of novelty that was going on in human society more rapidly than anywhere else.

That human society is itself a human creation was indeed a most daring idea. Vico first glimpsed it and stated it in principle, but it is to the courage and clear-sightedness of Marx and Engels that we owe its effective analysis. They saw society changing before their own eyes; they realised that they had to account for that change without invoking outside agencies. When they had done so they immediately saw the possibilities of extending the kind of creation of novelty that

they observed in human society to all other evolutionary processes in the universe, thus making it possible for the first time to understand it and cope with it rationally as a whole.

III

First and Last Things

The history of the universe need have no beginning or end. The further we go away from human experience into the vast expanses of time and space, the more difficult it is to analyse the processes that are taking place, and the more uncertain are the results of the analysis. The two things on which we cannot expect to be clear, and on which any apparent clarity would be completely deceptive, are the origins and the fate of the whole universe. We may reasonably hope to push our knowledge back stage after stage into the past, and with much greater difficulty, owing to its greater complexity, look a few stages further into the future. But we must judge a philosophy more by what it refrains from saying about the origin and fate of the universe than by what it says. Nor can it be important to us now, though it may be later, to know the more remote stages of our history, because these must provide the most stable elements of our present world and have the least direct effect on our immediate concerns.

All we can say safely is that there is now a certain connection between the fundamental laws of physics and cosmic structure; or, to put it in other words, that cosmos is a thing and process at the same time. The thing we have analysed into assemblages of elementary particles—protons, neutrons, electrons, mesons or any others which are yet to be discovered. The ways in which the process works are the laws of physics.

Galaxies and Stars

Two problems meet us at the outset. How did the odd hundreds of stable atom nuclei get formed in the first place, some in enormously greater numbers than others, and how did they come to agglomerate in the large and small concentrations that we call galaxies and stars? These are problems for the astronomer and physicist together, so far largely un-

solved, but at least they have shown that the heavier atoms are not being made now and that the stars and galaxies were once far closer together. The answer pointed to but unproved is the previous existence of a more concentrated universe in which the first atoms were built out of lighter units and where their very formation led to a critical state which was resolved by the condensation of stars and their scattering in whirls through space.

The stars themselves are impermanent seats of the most violent processes; some pulsate, others explode, others again spin themselves in two. The astrophysicists are just beginning to understand these processes and how they are linked with the properties of isolated atoms. Here again critical events are the rule. The break-up of stars may be intrinsic or provoked by a passing neighbour. It seems likely that the peculiar small bodies we call planets must have been formed in some such way, though we do not yet know the most probable mechanism. The result was to produce a state of affairs unlike anything that could happen on the larger and hotter stars. On a small, cooling planet, atoms which had previously existed isolated or in small simple molecules now found themselves closely packed into crystalline metals and rocks, and the properties by virtue of which they arranged themselves in an enormous variety of chemical compounds, though always immanent in them, were now revealed for the first time. The primitive earth itself in turn was subject to series after series of violent instabilities due to cooling of the crust, instabilities that we still do not properly understand but know to be the basis of most geological phenomena. A hard, inorganic world of gas, water and rock came into being. Oceans and continents, mountains and rivers were formed, broken up and re-formed over and over again.

The Origin of Life

All the time an instability of a far more significant kind was gradually building up, owing to the very conditions of uniform change that were occurring in the earth's surface. Here a number of chemical substances derived from the sea and a primitive atmosphere, which was unlike ours in that it contained little free oxygen and much carbon, were constantly being formed by the synthetic action of solar radiation. These

came into more and more complex reactions with each other, and, at some specially favourable time and place, their reactions became cyclical and indefinitely repeatable, so that complex molecules of certain types could regularly be built out of simpler ones. Here, in effect, is the origin of life; and, although direct evidence for this view will always be wanting, there is plenty of circumstantial evidence for it. It is relatively straightforward to determine what the atmosphere and conditions of the earth must have been without life. We can also see, by the extraordinarily limited and peculiar collection of molecules we find common to all living species, plant or animal, that once the first self-reproducing chemical associations were formed, the process became stable and stereotyped. The great step from non-living to living is essentially a physico-chemical step.

In the early history of life, the shapes and interactions of molecules were the only things that mattered. The achievements of that stage were the establishment of certain purely chemical transformations by which progressively more and more of the chemical environment could be incorporated in the organism, making it at the same time more resistant to changes in the physical environment. The greatest, perhaps the essential, achievement of early life, was the building up of the complex protein molecules which combine three properties that together form the basis of the physical as well as of the chemical activities of organisms. Each protein has a characteristic atomic pattern which can act as a firm mould for repeatable chemical processes. All proteins carry electric charges and react to the electrical charges in the environment in a way that provides the basis for sensation and movement. Some proteins can be changed into rigid structures of every consistency from jelly to horn, and thus provide the skeleton of the first definite living unit, the single cell. It is on the foundation of the regular chemical reactions of cells that are built all higher vital functions, such as sensation and movement. The understanding of biochemistry is the unravelling of the story of the origin of life.

Evolution

Now, although chemistry is the basis of life, it is only the beginning. Once life had got hold of the world, it in turn

produced new instabilities, but now these were inside the field of life itself, and led to the next stage, the development of the multiplicity of stably reproducing life forms, or, in a word, evolution. The appearance of each new successful life form is itself the outcome of a minor crisis in the relation of their parent forms to their environment, including other life forms. Gross changes in environment naturally favoured the development of one or other aspect of living ability, but the primary source of novelty was inside the living forms themselves.

In the process of that evolution entirely new structures and functions came into existence. The single cell no longer was the only self-sufficing organism; many cells growing together permanently, mutually assisting each other and having different functions, built up the larger animals and plants.

The need for food led in one direction to the mobility of animals in the pursuit or entrapping of other living structures. In another it led to more complicated syntheses in plants, through which they found the means of making use of universally present simple molecules. Growth and division are sufficient for the chemical stage of existence, but more complex sexual systems of reproduction arose from the difficulties of producing a viable small original which had later to develop in size and complexity.

As organisms grew in size, new problems arose, owing to the need of surface area keeping pace with bulk. The solution was found in the elaboration of tubular and branch structures in both animals and plants, and of internal circulatory systems to make existing surfaces more effective. The multiplicity of shapes that organisms assumed represented the material expression of the solutions of these physiological problems. In the animals that depended on their own bodily movement for acquiring food, the needs for mobility moulded external shape; head, tail, back, front, sides began to acquire significance. The problem of directed mobility solved itself by the specialisation of chemical receptors into the sense organs of smell, sight, hearing and touch. These in turn presented problems of co-ordination of sensation and movement, and this led to the development of a nervous system with its complicated behaviour responses.

Each new step in internal complexity corresponded externally to a better control of environment, and to a wider effective

range. Animals and plants together crept out of the sea to colonise the less hospitable but more rewarding land. Here it was necessary to provide a stable internal environment to cope with the much greater variations in the external one. The warm-blooded animals that succeeded best in this became the dominant forms. Among these we may discern man's ancestors.

The Origin of Mankind

The possibilities of a step in organisation leading to a higher order of complexity than any that could be obtained by an individual animal had already been achieved by the social organisation of many of the insects. But insect communities were absolutely limited by the physiological restrictions of their members which kept them small and fixed their behaviour patterns along rigid lines. Social development among birds and mammals had no such limitations. The conditions required for a permanent stable animal society were that its members should possess a certain degree of primitiveness of structure, good hand–eye co-ordination, and a long pre-adult stage during which the young could learn from the old. All these were developed among small tree-running animals which escaped the specialisation of the wings of birds or of the hooves, horns, fangs and claws of the larger ground beasts.

The origin of human society marks a sharp new level of complexity in the universe. It was, of course, not a sudden thing, and it would be impossible to say at what precise point we should consider it was achieved. Nevertheless, the characters of the earliest human societies of which we possess bones and tools show an enormous gap that had been built up already between them and all other animals. We are apt to think that this gap is due to some fundamental internal difference between men and animals. The materialists of the last century claimed that it was due to a superior brain, not realising that this explained no more, if as much, as the mediaeval attribute of an immortal soul. The real distinction is not to be found in man, but in mankind, in human society, two characteristics of which are cumulative tradition and progressive domination over environment. The enduring tradition of common action supplementing individual learning based on instincts and bodily adaptations helped man to make

the most of an existing environment. The cultural and mental aspect of man's uniqueness are two aspects of the same thing.

Man was to find later that animals taken young and fed and handled in certain ways could have their behaviour so modified that they became almost different species. But before man had learned to domesticate animals, he had domesticated himself. Until very recently, little attention has been given to the extremely elaborate, and almost purely traditional, process by which, from the very moment of birth, the human infant is moulded into the pattern of the society in which he is born. At first handling and gestures, then language, and later all the civilised elaboration of writing and radio, are simply successive means for establishing and maintaining a continuous conditioning of human beings to society.

Co-operation and Tradition

This conditioning would itself never have developed if human society had not been able to provide more for the individuals it comprised than they could get by their unaided efforts. Every trick of getting food, or of avoiding danger and discomfort, was now common instead of individual property. Joint exertions, mutual help, multiplied many times the power of the weak individual; and soon external objects, sticks, stones, began to be turned to use as an extension of natural limbs, at first in the raw, then shaped, then combined together to make tools, implements and finally machines. All this was only possible because every new technical advance had a chance of being incorporated in a spreading and continuing tradition. This is not the product of the human brain; it is the human brain which has been obliged to acquire knowledge and to complicate itself in order to deal with the material that society was presenting to it.

The first human groups already represent an enormous advance on animal ways of living. Instead of depending on one way of getting food, they had many that could be interchanged. They also acquired, through the use of skins, caves and primitive shelters, the possibility of a greater independence from the weather than had their ancestors. As the possibility of tapping new food supplies increased, so did the range of human groups. An important step came when stone weapons

were developed sufficiently to kill large animals. This put man on an equality with the lions and the wolves, and gave him the freedom of the plains on which ranged the herds of oxen, horse and deer.

The Foundations of Social Life, Kinship and Kindliness

It was while man was a hunter that he built up the foundations of social life which still live on in us and give us our deepest human feelings. Primitive society was based on the tribe, which was essentially a collaborating economic group established on common parentage. But it was not established on the family as we know it today. The researches of anthropologists have shown that the early families were based more on group than on individual relations. In the first place, relationship was traced through mothers and not through fathers. This, which is probably a relic of the time when the function of fatherhood was unknown, did not mean that the women ruled the clan, but it did mean that they assured its continuity.

Inside the clan, and inside the group of clans forming the tribe, behaviour and relations became strictly regulated by custom. Common work and mutual assistance was the rule. There were no rich or poor, lords or servants. Food was collected by each according to his special capability, the men hunting and fishing, the women gathering roots and berries; and all shared the produce in common. From that early tribal life, rough and insecure as it was, we have inherited the deep-rooted feelings of comradeship, equality, and the need to help our fellow man. These feelings have always persisted, in spite of being overlaid by later civilisation with its stress on individual acquisition of property and domination over inferiors; and it is to these deep-laid feelings that we must appeal in rebuilding human society in its present scientific and industrial phase.

In primitive society, however, loyalties and good feeling were limited to the tribe; obligations did not extend beyond the kinship groups. This did not mean that tribes were always at war. War, in fact, had not been invented, because the need for it on any serious scale did not exist. Tribal groups needed a wide and often shifting hunting-ground, and came but rarely in contact with neighbouring tribes. At most times of the year there was no surplus available for any enterprise but the

attention to their daily needs. But there was always time to think and play, and we know from what they have left behind that primitive men did develop, besides their practical work, a very rich and varied world of legend, magic and religion, not separated from but forming an essential part of their daily lives. They made pictures of the animals they hunted, they tended the bones of their dead in a way that shows that they thought of them as still living in some different way. We know too, from existing primitive tribes, something of the nature of their thoughts.

Language and Belief

Thinking itself was essentially a social occupation carried out, even by individuals, through language. It was natural that thinking for the first time about the outside world, the world itself should be pictured as social and human. If a stone was moved or some animal killed, it was because some tribesman had wanted to do it. If there was no tribesman apparent, then it must have been some invisible tribesman, one of the dead ancestors who no longer walked with them. Animals too were thought of as humans in disguise. Each clan had its own pet animal or totem. This human social way of thinking has not disappeared nearly so much as we may think. It still pervades much of our own views of things. But because we can now handle the evil forces of nature in a practical and material way, which primitive man could not, we think in this way only in the immaterial field, in considering such questions as morals or philosophy. The ancestors, totems and gods of the old hunters still live in our politics and religion.

The Limits of Primitive Society

The appearance of human society marked an enormous step forward from the animal state, but in its first stage social man had one important economic limitation where no advance had been made. Early society could only exploit but not control its animal and plant environment. It could exploit it in a more varied and efficient way than could any species of specialised animals; that is, unlike the lions and wolves, it could turn to eating plants if the game gave out. Nevertheless, human beings could only find support from the surplus left

by uncultivated nature. The effectiveness of the exploitation of nature determined the density of population that could be supported, and that density only amounted to about a family per square mile, which is a density only found today in desert regions.

So long as this limitation remained, human progress was severely curtailed. Units of population had necessarily to remain small, except for short times in special favoured places, where large herds of animals congregated. What is more, it put human society at the mercy of the changes which affected the animals and plants towards the end of the Ice Age. In the north, forests began to spread over what had been open hunting country; the animals left when the woods came and men were faced with the alternatives of following the fringe of the retiring ice, becoming the ancestors of the present Eskimos, or of finding some new way of life.

Agriculture and Civilisation

Somewhere between Syria and India that new way was found and the first great revolution in human society occurred. Man, or probably woman, because plant-gathering was woman's work, somehow discovered that edible plants could be made to grow more abundantly if they were tended, and even more so if their seeds were deliberately put in the ground. To catch and kill animals and eat plants as they grew was only to continue what their animal ancestors had done; but deliberately to interfere with the growth and reproduction of plants was something radically new and human. The discovery of agriculture together with the care and breeding of animals was the basis of civilisation. From following the herd to pick off what calves and weaklings could be caught, man turned into a herdsman, protecting his flocks, feeding them, and thus attaching them to him. By combining agriculture and pasturage the advantages of each were multiplied; the new fields gave more food for the cattle, the cattle increased the fertility of the fields. In favoured places, first in upland valleys and then down in the big alluvial plains, which before had been wild jungle, the new way of living spread. The first effect was to make possible an enormous increase in the density of the population, because now man had passed the critical stage and

become a producing animal, not only an exploiting one. The loose tribe became the village, and with the village grew up new arts, first pottery and weaving, then the crucial discovery of metals.

The Spread of Agriculture

With abundant food, population increased rapidly, so that the capacities of the new agriculture soon became strained to their limits. But at first there was an easy way out, simply moving to new lands. The whole world could now be thrown open to agriculture. The peasants with their small herds moved slowly and steadily over mountains into new valleys, halting only where the sea or the desert formed an impassable boundary. Century by century the peasants filled Europe and Asia and the greater part of Africa, passed across the Behring Straits and covered the Americas from north to south.

All this took time. In remote districts it is still going on in our own days. The peasants who moved could not carry much with them. The cultures they formed were poor except when they could settle in some specially fertile spot such as the plains of Hungary or the valleys of Mexico. But those who stayed behind, especially along the big rivers of Mesopotamia, Egypt and India, had the opportunities and the surplus of hands for a much more intense and rapid development. There civilisation concentrated and diversified itself. To till the great river plains, co-operation no longer of tens but of thousands of people was needed. Dams had to be built, canals dug, and this meant order and government. The very prosperity that agriculture had brought helped to disrupt the old limited tribal organisation. In the short time of a few centuries, intense human co-operation had brought forth all the leading characteristics that we now recognise as civilisation, and produced a form of material and social life which is still the one in which we pass most of our time. Villages clustered into cities, the customary exchange of produce between kinsmen degenerated into trade, and with trade came trade marks, which became mathematics and writing. With trade too came the break-up of the common sharing of tribal society. Grain and animals could be owned, and with ownership grew up the new distinctions of rich and poor, master and servant. Civilised man even

went to the limit unthinkable to savages and treated other men as animals, owning them as slaves.

Wealth and War

In this way, for the first time in history, some men could live without working with their hands. A very few of them spent their leisure time in developing literature and the sciences. The majority turned to the acquisition of more wealth, to wasteful spending and to fighting. The institution of war grew out of the development of cities. It was no longer a matter of dispute over a hunting-ground which could be fought out between a score of tribesmen with little more violence than a football match. It was now a matter of thousands of acres of good land, to secure which hundreds of peasants, armed and armoured, and led by their lords in their war chariots, would fight and kill each other for weeks at a time.

The positive achievements of the new civilisation were those of peace and trade—houses, fine clothing, wheeled vehicles, ships, mills and irrigating machinery; bread, beer and wine, architecture, painting, sculpture and drama; kings and courts, priests and temples. Here was laid the main framework of our way of living today. The mechanical age has given us enormously enlarged powers of production and transport, but as consumers we demand much the same things as men wanted six thousand years ago.

The Legacy of Early Civilisation

Agriculture and early civilisation transformed and added to the traditional heritage of the tribal hunting-man, the peasant virtues of hard and unremitting work, of regular habits and attention to the successive tasks of the changing year. It profoundly changed the carefree attitude of the primitive savage, but with peasant virtues there also appeared for the first time the acquisitiveness and meanness which are inconceivable in a tribal society. In the towns the craftsmen and traders developed the traditions of good workmanship and fair dealing, but with it a narrow sense of private property and vested interest. The new social values were never harmonised with the old; already the struggle inside the human mind between the earlier gener-

ous social impulse and the newer individual selfishness had begun.

Social Discord and the Barbarians

The first brilliant development of civilisation did not last because the element of social discord that it brought continually frustrated it. After about 3000 B.C. it was clear that technical improvement was slowing down, and indeed the same rate of development was probably not reached again until the seventeenth century of our own era. Civilisation certainly spread outwards. The Mediterranean, India, China, soon came to rival Egypt and Mesopotamia. But the quality remained static, so much so that for most people living it became the eternal order of things. Periods of peace and prosperity alternated with periods of famine, civil strife and war. The poor were always being ground down and they occasionally revolted, and around the fringe of civilisation lay the barbarians.

These barbarians were originally simple peasants and herdsmen, but they were always being interfered with by their civilised neighbours who came into their lands first in search of gold and minerals, and then to trade for raw materials, giving them in return ornaments, weapons and drink, and teaching them the dangerous art of war. With unfailing regularity, when political strife in a civilised country reached a certain level, the weaker side would call in the barbarians as hard-fighting allies. Sooner or later they would come into residence, and take over the country itself. The result was that all over the civilised world government became barbarised. The barbarian rulers might acquire the external features of civilisation in dress and ornament and extravagance of life, but they retained their tradition of barbarian values.

The result was to confuse still further our traditional inheritance, particularly since barbarian values, which compound the acquisitiveness of the merchant and the violence of the tribesman, were never common values but were limited to the ruling classes with which the barbarians merged. Most written history is a record of the working out of the pride, greed and violence of the barbarian rulers and aristocracies. We see these even today in the habits of the Nazis. The tradition of the common people was also profoundly modified by barbarian rule. Each

injustice and loss of freedom combined with old superstition into an attitude of profound acceptance and resignation to the will of God, as exemplified in the social structure. Religion was always for the common people, and aristocrats were above it.

The Spread of Civilisation

The process of interaction between civilised and peasant communities just sketched is one which occupies the greater part of recorded history. Through its agency civilisation gradually spread over the surface of the world, but it spread from its focus in the Near East in a characteristic, uneven way. At the outer fringe, among the barbarians, was a boundary of pioneers, merchants, miners and hunters, who linked the civilised world with the uncivilised. Next to them were the most active and at the same time the roughest and most violent civilised states, themselves partly barbarian and, in their aggressiveness, breaking out not only in further annexations over primitive peoples, but in reactions on the older civilised centres lying further in. In classical times, first Greece and then Rome had the character of a border state; later it was to be France, Holland, England, Russia and the United States of America. In the east, the continual revolutions of Chinese history mark the same type of spreading process from the Han valley to the Yang-tse-Kiang and beyond.

At the very centre there remained the old, original civilised states, losing first their initiative, then their independence and ultimately decaying back into a state of culture far lower than that of their own past or of their outer neighbours. This decay was already conspicuous in Egypt and Mesopotamia a thousand years before Christ. By the end of the Middle Ages it involved the whole of the Near East and most of the Mediterranean countries. In India and China it was arrested by the persistence of the original peasant cultivation of irrigated land.

The Cultural Heritage

The outward spread of civilisation did not, however, leave it unchanged. The new centres of civilisation were now consciously aware of the heritage they carried from the old. They developed their own culture on the basis of a set of ideas

—political, religious and artistic—that they drew from the older civilisation. Christianity, for example, was originally one of the mystery religions produced in the disturbed and tragic times of the break-up of the old Asiatic kingdoms by aggressive Greeks and Romans. It became later the state religion of a great but already decaying Roman Empire. As the only live part of classical culture, Christianity was taken over by the active barbarians, and though changed in the process, it gave a unity and a continuity to the Dark Ages that they otherwise would not have had. A variant of it, as Mohammedanism, had the same function for Africa and Western Asia.

Common to both Christendom and Islam as heirs of the classical civilisation was a body of literature, philosophy and science, not very clearly differentiated, which had been elaborated, mostly from earlier sources, by the Greeks and which passed into the tradition of the learned classes all over the world. Extending even wider still was a set of purely practical recipes and trade practices—in agriculture, mining, metal working, weaving, pottery and architecture—which were handed down from master to apprentice from earliest times. The very structure of society itself was also a common heritage. As civilisation spread it carried with it the same pattern recognisable through all its local variations. In the country there were land-owners, usually nobles; in the towns, merchants and craftsmen. All lived on the food produced by the villagers, whether slaves, serfs or free peasants.

The Movements of History

Though civilisation had established a pattern, it was by no means a static one. The balance of importance of different classes and groups in the civilised world was continuously changing. In certain areas and for certain times merchant republics might be dominant. These merchant republics always proved unstable. Based upon organised greed, they inevitably oppressed their labourers and other poorer citizens, while their wealth invited looting by their more vigorous and less developed neighbours. The greatest flourishing of such merchant republics was the federation we call the Roman Empire. This broke down, not so much from external attack

as on account of the ruthless exploitation of the people, as slaves or poor villagers, by the owning classes.

After the collapse of merchant republics usually came the turn of the rule of the landed aristocrat—what we call the feudal system. This was more primitive in material culture, the land being broken up into innumerable domains with peasants unable to do more than maintain themselves in poverty and their lords and their fighting men in hearty well-being. Feudalism was not confined to Western Europe; at different times it flourished in the Near East, India and China. But it too was an unstable state, dependent for its existence on continual warfare. As long as war was the rule, the poverty and uncertainty necessary for the feudal system remained, but once a particular lord was more successful than his rivals and established some form of peace for his own profit, the merchants and townsmen began again to flourish. And as soon as the lords felt the advantages of the money that these provided, they came into the merchants' power and lost their own which was based on land and arms.

The perpetual warfare and social struggles, the change of dynasties and republics, might seem to have been the normal lot of humanity, and it was certainly so seen by the men who lived in these times. But the outward movement of civilisation itself ensured that this process could not maintain itself in such ceaseless revolutions without at some point engendering fundamental changes. As civilisation spread it passed into new lands and here the conditions were fundamentally different from those of the lands of its origin. In the first place, civilisation left the broad, irrigated river valleys that ensured the density of population that made possible its first flourishing. It was impossible in the poorer lands of northern Europe to produce wealth for the lords simply by the patient labour of thousands of serfs or slaves. The desire for wealth was there and new means had to be found to achieve it. It was not until the barbarian and later the feudal states that succeeded the Roman Empire had finally settled and achieved some degree of peace and mercantile prosperity that this change could take place. That it took place in Western Europe and not in any other part of the world was largely a geographical accident. The nearest competitor was China, but it was some centuries behind.

The Dawn of the New Age

In ordinary history we read of the changes that took place in Western Europe as the Renaissance, the Reformation and the Industrial Revolution. But these were merely outer forms of a vast and critical transformation in human affairs. Not until recently have we been able to glimpse at the obscure and patient movements that led up to these changes. Steadily through the Dark and Middle Ages, technique was improving to meet the harder demands of cultivation in the poorer lands of Europe. The invention of the horse-collar threw open to the plough millions of acres of rolling country. The miners developed wooden pumps to tap the deeper veins of ore, and spread their activities into the wild mountains of the Ertzgebirge and the Carpathians. The shipwrights introduced the rudder and the practice of sailing into the wind; and turned the compass, which was borrowed from the Chinese, to good purpose in crossing open sea. Two other borrowings from China were equally important—gunpowder, which gave its users, backed by the metal industry, an immediate military superiority; and paper and printing, which spread literary culture, personal religion and political consciousness among the whole of the mercantile classes.

The technical basis for a revolution was there; the economic impetus came from the new growth of the merchant classes following the decay of feudalism. The initial success which started the revolution with an impetus which it never lost was one of adventure and robbery. The new armed ships seeking cheaper luxury goods were soon dominating Eastern Asia and almost accidentally discovered the practically unexploited regions of the Americas. Now there was wealth to be had for all who could take it, but to take wealth, hands were needed and hands were scarce. Every effort was made to supply these hands in old-fashioned ways. The Indians of the West Indies were enslaved, but they inconsiderately died. The slave trade was revived and thousands of negroes, and white men too, shipped to the new plantations, but there were never enough; more things had to be done with less men.

The Birth of Capitalism

The need was urgent; the economic organisation and the technical basis were already there to satisfy the need. The

accumulation of money that had been made through trade and exploitation could be used, not as in past times, merely in buying up land and forming the basis for a new feudal system, but also for the new processes of manufacture, the organised production of goods by men working for wages. This system we now know as capitalism. In itself it was not anything radically new. What was new was the improvement of manufacture through the development, first of machines in which complex processes could be carried out with fewer hands, and then of engines which met the need for heavy work better than animals, wind or water. To invent machinery did not require in itself any superlative human ingenuity, but it did require, in its very first stages, that a special advantage should be gained by saving of labour, and this could only occur in a civilisation in which labour was a scarce commodity. Hence it came that in Western Europe and the new colonies human ingenuity was turned more and more consciously in the direction of mechanical invention.

Technics and Science

Yet the process was far more than one of technical change. It has always been characteristic of the craftsman that he advances in small stages, adopting new processes only if the old ones have proved unworkable or unprofitable. To advance more rapidly it is not sufficient to know that if certain practices are followed they will yield satisfactory results. To know what big changes can be made safely or advantageously it is necessary to go further and to find out what the old practices were based on. Knowledge of the behaviour of matter and natural forces is an essential prerequisite to big technical changes. But the very circumstances which led to the demand for new techniques also provided the opportunities and the incentive for acquiring this knowledge.

The first successes of the new techniques, particularly in navigation in the discovery of the New World, broke down reliance on traditional knowledge which was also being heavily shaken in the social sphere because of its association with the feudal pattern of economy. A by-product of the literary and theological interest of the Renaissance and the Reformation was the interest in the world of nature and even more in the world of art, including, for the first time since before the days

of Greece and Rome, the practical arts as well as the fine arts. Modern science was the result of this renewed interest, spurred forward by the need for technical development. The earliest scientists were naturally most conscious of this connection. The works of Leonardo, Galileo, Bacon, Boyle, and even of Newton are full of their consciousness of the fundamental utility as well as of the beauty of science. That connection was largely lost by the nineteenth century. We are beginning to rediscover it now.

The Industrial Revolution

Once new techniques based on new knowledge securely established themselves, the process of further development became automatic and increasingly rapid. The profits of industry led to further accumulations of capital, to further investment and to a more rapid spate of inventions and discovery. The critical period for the transformation was at the beginning. Early machinery was necessarily highly inefficient and cumbersome, and it had to compete with a craftsmanship perfected after many centuries of natural selection. It was only when a process such as spinning or weaving could be done by the early crude machines many times more cheaply than it could be done by hand that there was any chance of introducing it; but once introduced the new methods improved while the old stood still, and rapidly broke up the economy of the older society. The craftsmen and the peasant ceased to be independent self-sufficing producers. Nearly all the former and many of the latter were swept into the factories; the remainder grew cash crops for the market they could not control.

Paradoxically, the movement that started from a shortage of labour provided very soon a far greater labour force than had even existed before. The human race, which had maintained a static population for many centuries, suddenly began to multiply to fill the new factories and to produce food from the new lands. The new population in turn raised new demands which only mechanised industry and agriculture could provide. Increase and improvement seemed self-perpetuating. Indefinite progress became an axiom, and progress implied free trade and capitalism with its trinity of rent, interest and, above all, profit.

The Second Human Transformation

The scientific industrial transformation is the second great change since the origin of humanity. Mankind, properly speaking, came into existence when, through society, men were able to exploit nature collectively; but though then they could do more together than they could separately, mankind collectively could at first only live on the available surplus that wild nature produced. The first major change was the introduction of agriculture. Now man controlling through his understanding certain plants and animals, was able by his crops and herds to secure a more thorough exploitation of the primary resources of land and water. Still, for the greater part, motive power came from human or animal muscle, and materials were drawn without fundamental alteration from the earth, plants and animals. The agricultural stage was essentially a socially organised control of biological environment. The second change ushered in by the scientific or mechanical revolution went one step further—the control and exploitation of inorganic natural forces and materials. It implies an understanding of a different character from any required before. The understanding necessary for the first stage was essentially social and human, embodied in tradition, ritual and magic. For the second agricultural stage much more was needed—a knowledge of the growth and reproduction of plants and animals, of the properties of wood and stone and fibre and clay and even of the artificial metals. But once gained, it could be passed on as traditional craft knowledge.

The third stage makes far greater demands on human understanding, and these are not limited but progressively increase as the scale of exploitation of natural powers increases. Here rational and scientific analysis takes the place of traditional thought. Thus the second transformation is a transformation of human mind and human society no less than of the material basis of life. The social implications of the birth of science and of the industrial revolution made themselves felt from the very start of these changes, but they were not consciously understood until the work of Marx and Engels. It took a long time for the ruling classes, even though they had grown rich as a result of these changes, to recognise their existence; and when they were at last in the nineteenth century forced to recognise

them, they treated the changes as due to some particularly providential progress which had also the value of increasing their own wealth and importance. Modern civilisation, with its steam engines and telegraphs, was felt to be inseparable from factory-owners and stock exchanges. They went even further and considered this entirely novel and fundamentally transformed society as being the natural order of man: that the use of it had been denied the past ages because of their ignorance, not of the technical basis of modern society, but of its economic and social forms—free trade and joint stock companies.

Science and Capitalism

People are now much less likely to accept the modern world as a natural order of things; progress, in the old sense, has so clearly broken down. But in their rejection many still confuse the technical and scientific with the economic and political factors. Because the situation is intolerable, they blame science itself and the techniques that provide the forms of destruction and misery rather than the social factors which have led science and technique to be used in that particular way. Now just because the difficult birth and the struggling youth of the scientific and technical conquest of material environment occurred—and could only occur—under conditions of capitalism, it does not at all follow that capitalism is necessarily and permanently associated with these transformations.

In fact, we have already a large-scale demonstration that this is not the case. The technical, the organisational and now even more the military failures of the leading purely capitalist states stand in sharp contrast to the successes of the socialist organisation of the Soviet Union. The reasons for the failure of capitalism to live up to its early promise were mercilessly laid bare by Marx at the very heyday of capitalist enterprise in the middle of the nineteenth century. It was the social failure of capitalism, which in turn depended on its economic organisation, that in the end destroyed the value of its technical achievements. The vast new population which was almost brought into existence by the industrial revolution was not a population which enjoyed more than a minimum of the benefits of that revolution, the minimum necessary to keep them alive and at work. The vast majority of the population of the world

became either wage-workers in industrial countries or virtual serfs producing raw materials from the land and mines of colonial countries. Even though in favoured countries such as the United States there remained until recent times the possibility of the abler of the workers themselves becoming capitalists, these were a minute fraction of the population; the remainder could not participate to a sufficient extent in the benefits of that increased production to prevent the fluctuating and ultimately chronic state of overproduction with its attendant crises, unemployment, emigration and ultimately war. Capitalism was like the wizard's apprentice in the fairy story who knew the spell to make the spirits work but could not stop them. Today, even in the most developed capitalist countries of Britain and the United States, it is clear that the traditional forms of production for private profit are serious hindrances which must be largely abandoned if the war is to be carried on effectively.

The Decay of Capitalism

Long before the war started, however, the form that capitalism was taking was holding up rather than advancing progress. Already, towards the end of the last century, free-trade capitalism was passing into imperialism. Backward countries were no longer merely markets for textiles and fancy goods: they were fields for investment in railways, mining and factory equipment, to be worked by cheap native labour in order to bring profits to fewer and bigger companies at home. These companies were becoming more and more identified with the governments which supported them and which annexed to their empires the territories on which the companies operated. But once the whole world was divided up between the rival empires, even that possibility of capitalist expansion came to an end.

The characteristic features of capitalism in the last thirty years have accordingly been monopoly and restriction. Trusts, cartels, price-fixing arrangements have been made among firms, not so much to get vastly increased profits as to preserve profits even for inefficient firms, in a dwindling market, by limiting production. In the last stages since the great crisis of 1930, capitalists even went so far as to destroy, not only the products of agriculture, but also the very industrial means of production. Companies were formed, not to spin more cotton

or build more ships, but to destroy cotton spindles and "sterilise," as they called it, the shipyards. This policy, in those countries where it was most practised, as in England, went further and destroyed the bases of human economy; they produced an attitude of mind that was fatal to any constructive effort. The emphasis was all on caution, soundness and conservation; on the tame acceptance of the diminishing scale of effort. Unemployment, partially palliated by doles, was tolerated as the natural state of affairs. Stupid and unenterprising men ruled a people they had made docile and hopeless. Their attitude, which infected the whole of society, laid emphasis on the need to preserve status rather than to promote action. Trade-union and Labour leaders abandoned any hope of power or even of radical improvements and concentrated instead on preventing any movement that would endanger the position of restrictive monopoly capitalism. Anything, they felt, would be better than violent change in which working-class privileges or their own positions might be lost.

Fascism, War and Revolution

Violent change, however, was the one thing that could not ultimately be avoided, whatever efforts were made to put it off. Where revolution could not be dared, fascism and war took its place. The rise of fascism was simply the counterpart in less prosperous countries of the static pluto-democracy of the more prosperous ones. Where, for the lack of colonial territories and credit resources, the proportion of goods that could be spared to the working class was so low that even the most docile must react, a new and violent way had to be found to save capitalist forms. Fascism achieved this in two inseparably linked ways —repression within and aggression abroad. By making armaments the main problem of unemployment could be met. By using those armaments in war, the populations of other countries could be robbed of enough to support the aggressors. By a state organisation, capitalist enterprise could be shown that there are ways of profit other than by restriction, while the whole apparatus of party brutality and police spying could carry out the necessary task of suppressing conscious working-class elements. By the beginning of the 1930's capitalism had no way out but fascism and war, and it was merely a question of how far fascism would spread before war broke out.

Socialism

But although capitalism is producing its own destruction through its very success in mastering material environment, it has also provided its own successor in social organisation. There is no need to lose the advantages that capitalism has brought to humanity. In fact, the way in which those advantages can be fully realised is indicated in the development of capitalism itself. Marx characterised capitalism as an increasing organisation and socialisation of the *mode* of production unaccompanied by the socialisation of the *products* of industry. Since Marx's time, the degree of organisation of production has increased enormously and it is now apparent to most intelligent people in the world that this organisation could be used effectively for general benefit if we could solve the purely human and social problems involved in the transition from the vested interests of the few to the common interests of all.

The problems involved are no longer technical but political and economic. There is no need to abandon the slightest advantage of scientific and engineering skill or of organisational ability. True, we are only just beginning to effect the mental transformation that has accompanied all the large human transformations in the past. The first stage in this transformation was the realisation—of which Bacon was the greatest spokesman—of the immense new powers which science could give humanity. The stage we are reaching now is the realisation that those powers will be of no use to humanity unless the whole of human effort on a world-scale is consciously organised and integrated. We see that particular solutions, where they are in the hands of a class or an imperial state, are worse than useless.

This consciousness of a collective human task is as important on the mental side as technical achievements are on the physical. It might have been imagined that it would come most easily to those who had been directing technical and economic development. But this in fact could not be, because of the very nature of capitalist organisation. The directors of industry were necessarily at war individually with each other and collectively with the large mass of wage-earners. They were forced to deny, first of all to the population at large and ultimately to themselves, the knowledge of the need for con-

scious, co-operative utilisation of natural resources. Their failure in the last few years, exemplified on the one side in the fall of France and on the other by the perverted capitalism of Germany, shows that this self-deception was itself a prelude to general incapacity. The real consciousness of effective human unity could only arise on the other side, in the working classes, who stood to gain immediately as well as ultimately from such unity. Marx, Engels, Lenin and Stalin were among the leaders of those who analysed this, stated it clearly and realised it in practice. Their work has the validity that it has because of its inherent applicability to the present state of human development, so that millions of those who cannot understand the complexities of economics or have had no chance to study the history of civilisation are beginning to see what has to be done and can set about doing it.

The Soviet Union

Some have done more than begin to see it. In the Soviet Union for the past twenty-five years the working class has begun the building up of the new civilisation. The task was difficult and bloody from its outset, hampered in every way by the interference of outside capitalist states, by the stupid greed and superstitions of internal elements attached to old forms of living, and, finally, by the murderous attack of the Nazis. The common people all over the world are beginning to see in this last phase what only a few of them were able to see before through the mist of lies and belittlement spread about the Soviet Union. They see its enormous material strength, its capacity alone among democratic nations to withstand the full fury of a nation trained first and last for arms and having behind it the industrial strength of the whole of western Europe. But they see more: they are realising that the material strength of the Soviet Union is an expression of the people themselves, a new people made by a new society.

The Communist Party

The establishment and building up of the Soviet Union was no accidental or purely Russian phenomenon. It was the logical outcome of the workers' movement of liberation from the injustices and restrictions of capitalism. Marx and Engels

had given the movement consciousness and direction. Lenin, after decades of revolutionary activity, was to lead it to its final triumph in Russia. The weapon he forged and led was the Communist Party—the Bolsheviks. The Communist Party, although it derived from both, was not a political party in the old sense, nor was it a revolutionary junta like the Roundheads, the Jacobins or the Fenians. It was a new type of organisation suited to the conditions of transition to the new form of society. It had discipline, unity and earnestness of purpose, but it imposed the obligation on its members to combine their practice with understanding and learning. Every communist knows that he cannot be effective unless he understands the historic process of which he is one part and unless he tests the validity of that understanding in his actual daily work. It is no question of applying mechanically the texts of Marx or Lenin, but of learning from the people what is their applicability and how they must be developed. The Party ensures the purposeful, determined and resourceful co-operative action that has been so well shown throughout the history of the Soviet Union, never more than now, and shown as well in China, Spain and many another oppressed country. The Party does not stand as a hand-picked élite responsible to an autocratic Führer over a cowed and apathetic populace; it is the devoted, conscious element of the people themselves.

What has been effected in the Soviet Union is more than the building up of a socialist economy. In winning and defending it, the many peoples of the Union have found themselves; they have renewed hope and initiative in life. The contrast of the old and new life is nowhere more clearly seen than in the once backward peoples of the Union. Following the national policy initiated by Stalin, they kept and fostered their traditional culture but built up at the same time a fully modern and scientific industry and agriculture. The result has been to create eager and progressive peoples fully capable of defending themselves against any aggressor. The war has taught us that where populations lack that effective self-reliance, as in Malaya and Burma, the task of defence is practically impossible. Along the path already blazed in Soviet Asia and China lies the sane and democratic way of solving, in a few years, all our racial and colonial problems.

Social Transformation

Transformations of a fundamental kind, though they may take years and even centuries to prepare for, come, when they are ripe, with startling speed. Changing societies are full of violence and apparent cruelty: the cruelty that unhesitatingly sweeps aside all the sentiments of people who for one reason or another cannot adapt themselves to the rate of change. But they are also periods of vast enterprise and growth of human stature; they create men of ability; they liberate thought; they enable great works to be carried out; internally the whole individual pattern of life is changed; the goal of human hopes is no longer individual domestic wealth and security but accepted collaboration in an active, working and developing community.

Historians used to refer to the change from feudalism to capitalism as one from status to contract, a change from an economy where one knew one's place to one where one paid one's way. This change is now being reversed, but in a dialectic way. Contract is returning not to status but to function. What a man does in his right place with other men is his wealth. The new socialist state will have to combine together integral organisation and democratic initiative. These are not irreconcilable opposites. Soviet experience shows this every day. Nowhere is there such initiative and improvisation; nowhere have isolated groups proved themselves more capable of finding out the path to action for themselves. Nevertheless they are all sustained by a common purpose and work together to a common plan.

The period of rapid change is now working up to its greatest speed and violence all over the world. Countries are taken overnight; empires crumble in weeks. The social system of centuries has now become an artificial shell which is only restricting the capabilities of the human forces inside it. However varied are the fortunes of war, one thing is lost for ever—the old world. The second great transformation of humanity is visibly under way.

IV

The Function of History

In the new stage of humanity to which we are tending the consciousness of history in its widest sense will be a most important moving force. We need this consciousness now more than ever to take our bearings in the present chaos. History is not merely a record of what has happened or even an indication of the direction in which human society has moved: it has begun to tell us why it has moved in that direction and how its present movement is related to our own activity. Philosophy and history have now begun to regain the function that they served when they were first distinguished in classical times. They are as much a motive for action as a guide to how that action should be carried out. Through our greater knowledge and deeper understanding we can now see our place in the universe far more clearly than it was ever possible for men to see it before; but in discovering it we also find that that place is not something settled for us once and for all, to make the best of, but is something we have contributed to making and we will contribute to changing. In this realisation lies also an understanding of the general motives of our own actions. This understanding is no longer passive; it is because we can see why we have done things, and are doing things, in relation to the social movements around us, that we begin to see and to feel why we should do things. This new philosophical and historical outlook will serve to integrate human society as effectively as but more intelligently and flexibly than did the religions of past ages. In the first stage of society it was sufficient for each group of tribes to have their own local and personal gods, who were, in a quite literal sense, the fathers of the tribesmen. The growth of territorial empires, with their attendant big cities and slave countryside, fitted and, indeed, gave rise to, great world religions. These religions were now for all men instead of for restricted groups, but they were also religions for all time, fixed as they were to the conditions of agricultural society. In the third stage of humanity we need no religion in either of these senses. Man no longer needs to compose anonymously and collectively a canonical account of the world he lives in and of his duties in it.

Instead we have a continual search for conscious understanding on one side and planned co-operative activity on the other. The new society, the progressive understanding of it and the progressive moulding of it, run together as aspects of the same process.

Society and Human Nature

The new society is not merely a new regrouping of the men of the old society; it is a society of new people. The outlook, the character, the values, the habits and moralities of men are, in spite of their manifest personal differences, the product of the society that they live in. Just as the hunting and agricultural stages of human development have left their mark on human character, so will the equally great changes towards the conscious and scientific society affect the spirit and purpose of men. That change is already under way. As Lysenko has said, "Men are not born in the Soviet Union; organisms may be born but men are made." We must learn to understand how much of what we think of as fundamental human nature is the product of our own upbringing and our introduction into a mercantile society.

The things that people seek for in their lives, the eternal values of the philosophers, do not become any the less real because we have found that they are relative and determined by social forms. This relativity is itself an absolute thing—the only "absolute" there is. We live and work and feel and enjoy in society and through society. The values that correspond to our relations with the new society will be just as important and deeply felt when they are consciously understood as they were when they were mystically accepted. No band of irrational fanatics could show more devotion than the people of Stalingrad, who know that they are fighting a historic battle to establish a rational, full and hopeful life for all men.

The classical values of truth, beauty and goodness depend for their meaning entirely on the existence of society and change their character with the change of that society. The word "truth" stood originally for traditional loyalty. It still stands for the kind of judgments that will receive the assent of humanity at large because they are found to work: that is, they can be relied on not to lead people to expect things that do not happen. A great deal of truth is pure convention, but its value lies in that, as long as the convention is accepted, it

does not lead to confusion. This does not mean that anything that can achieve social assent is true: the door is not open to the perversion of pragmatism. Nazi truth is of this character; it worked supremely well until recently for the Nazis themselves: the others have had to take it. Nevertheless it is not socially determined truth because it is for ever running into the contradictions which are brought about by its rejection of common humanity in exalting a particular gang. These contradictions express themselves, both inside and outside Nazi Europe, in revolt and armed resistance. The truths that are not social—so-called scientific truths—have an appearance of a far more absolute character; their verification lies in experiment; but they are also relative in a different way. No scientific truth is static: it is continually acquiring wider and deeper meanings which always change it and may sometimes appear to contradict it, as quantum mechanics did classical mechanics. In fact the new truths contain the old truths, representing a further stage of social conquest of the outer environment. But they contain them and more. The fact that we have seen this process happening does not lead to scepticism but to a concept of truth much more alive and active than the eternal verity of the ancients.

Beauty has always been a more admittedly social attribute than truth. We know how style and fashion continually distort established values; but again this variability does not diminish the reality of beauty. It is inherent in the common social enjoyment of things either directly pleasing our senses, such as food or flowers, or indirectly referring us to some moving or amusing social occurrence. The beauty of socially created forms, the beauty of art against the beauty of nature, depend just as much on the people who are affected as on the artist who creates. We suffer today from a dislocation of appreciation of art forms. There is no common humanity to appeal to. Instead we have the distinct popular and highbrow arts which correspond to the differences in social education. Every work of art is expressed in a language of its own that has grown up through a long tradition and can only be appreciated by those who have some hold of that language. Only in a society where all are brought up alike and share in a common heritage can we hope to develop a fully integrated art.

Goodness is purely social: there is no such thing as natural

goodness. Society itself depends for its first origin and existence on goodness, for unless the most primitive men were prepared to give and take, there would have been no society and no humanity. And yet the standards of goodness or our feelings of goodness seem, if anything, more absolute to us than those of truth or beauty, and they are so because they were founded deeply in the framework of society. When society changes, goodness must change too; but the old good things—fellowship and kindness—remain as part of the new goodness though further demands in behaviour and feeling may be added to them.

New Morals and New Values

Religion and morality are the mythological and unconscious expression of the form of society itself. We have had, actually for many years, two moralities which dovetail into each other: the Christian morality of submission and the capitalist morality of self-help. The first is aimed at the working class, inculcating unthinking acceptance of the social framework. The other, for the bourgeoisie, offers hope of escape from drudgery and frustration through the acquisition of wealth by hard work, saving and cleverness. There has always been a certain conflict between these two aspects of morality—a conflict glossed over by hypocrisy and the observance of "Sunday religion." But as far as action is concerned, the Christian religion had long ceased to interfere with business practice or business morality. Conventional Christian morality had lost whatever it had had of a positive character, in seeking the Kingdom of God on earth, and had become entirely negative as a series of avoidances of certain acts—murder, stealing, adultery—leaving men free to pursue wealth and make their fortunes within the bounds of a very lax commercial law. Some of the prohibitions of religion were old agreements necessary to preserve any human society from the recurrent violence of blood-feuds, but most referred to the breaking of conventions necessary for a reliable commercial intercourse. The positive elements of business morality were exclusively economic—at least to pay one's way, to support one's wife and family; at the best to make one's fortune and achieve success.

We have been trained, of course, not to consider these positive elements as morality at all, but simply as things that

everybody did and we ought to do ourselves. Officially, morality was confined to the avoidance of certain sins. That hypocrisy must be seen through before we can begin to appreciate the new morality which must grow up to fit a new state of society, for that morality must be essentially integral and positive. It must no longer consist of two parts, one publicly admitted, the other privately acted upon, but must unite action and belief. Liberty in its capitalist sense is really an expression of the negative aspect of morality, which says in effect—you must avoid certain things and for the rest you may do exactly as you like. An integral and positive morality says, on the other hand—there are certain things to be done and you should avoid anything which interferes with the doing of them.

The central demand of the new morality is that we should work our best with our fellows for a common purpose. This implies many demands both on the individual and on society that were never made before. It demands goodwill and co-operation; it demands intelligence and initiative; it demands unlimited responsibility for every action. These are not separate demands but linked closely with each other. The new society is not a society of instinctive robots like those of bees and ants: it is one of conscious and diverse human beings. It is not one ruled by a "Führer princip," in which each man is only responsible for carrying out the demands imposed on him by his superior. It is up to everyone to find his own place and to do his best in it, not for himself but for the society of his fellows.

That demands that he must think as well as act. He must understand what the aims of society are and he must contribute, not only to what that society is doing at a given time, but to what it is trying to do. He must help to change its course, to regulate its development. As Lenin said, "Every cook must learn to rule the state." A society guided by this morality is not one in which the individual is reduced to impotence but, on the contrary, one in which the individual has more scope for his individuality and at the same time is required to use his gifts more strenuously than in any earlier form of human society. The older moralities of humility and self-abasement are as much out of place in the new society as the later ones of independence and self-seeking.

Social Implications of Morality

To be fully effective such morality can only grow out of the society which fosters it. The demand that every citizen should know and understand implies an educational system which permits and helps—as our educational system does not—everyone to learn easily and naturally the workings of society and the place he can find in it. The demand that every citizen should willingly play his part in the productive machine implies that the economic form of society itself is acceptable morally, as even the churches are finding out that our present economy is not.

Only in the new society will man be able to recover a morality free from hypocrisy and conflict. However hard and restricted savage life was, it at least had that basic human fellowship that was destroyed at the beginning of civilisation through the institution of property and the growth of class divisions. Engels, in *The Origin of the Family*, foresaw that, once mankind had, through society, emancipated itself from the need of drudgery for the subsistence of the many and the comfort of the few, it would be possible to recapture unalloyed the savage virtues of fellowship, kindliness and hospitality.

At heart morality is not a question of codes or principles or even of reason: it is the expression of human feelings in behaviour to others. But the world of feeling as shown in personal relations, in art and religious experience, is nothing set apart from the material and economic world of fact. The old separation of matter and spirit has no longer any basis in knowledge. The distinction is real—spirit stands for the social elements in humanity—but at the same time both are linked together through the productive mechanism.

The separation of matter and spirit also fatally confuses our handling of the problem of values. To the idealist the materialist seems to lay all his emphasis on the achievement of crude satisfactions of money, food or sex and to ignore the higher spiritual values. This accusation, which never fitted even the mechanical materialists of the last century, is completely inapplicable to the dialectical materialist of the present time. Actually by not recognising spiritual things as predominantly social, the idealists have been forced into what is effectively a material position; that is, treating spiritual things as if they

were some kind of material with certain properties: different material and different properties from those of crude matter but equally absolute and equally unrelated to human beings and their history. It is no use realising instinctively and proving metaphysically that spiritual affairs are more important than material affairs when this realisation does not bring any power to achieve those spiritual aims. As long as spiritual things are not realised as socially directed, spiritual action is the only means available of achieving them, and however this may succeed in individual cases, apart from the deceptions of yoga and asceticism, in producing beautiful lives, it has not only failed to advance spiritual values generally, but actively opposed the conditions necessary for their development. It is no accident that St. Francis, the founder of mediaeval mystical piety, and St. Dominic, the founder of the Inquisition, were men of the same age. Spiritual ends are higher than crude material ends, not on account of any mystical quality but because they are essentially social ends, and society is a later and more complicated phase of universal history. But because they are social ends they must be realised by social means, that is, at the present time, by the conscious organisation of society which includes the necessary provision of the material basis for that society. This end cannot be achieved any longer unconsciously and by individual action. The value of the individual is still the highest value but only through and in the society which has made him and which he makes.

Our values in art or conduct are conditioned by social history and react on it. The achievement of the best social environment is an aim inseparable from that of the best biological environment. At the time when individual material gain seemed to be the only thing worth struggling for, the teaching of Jesus stressed the need to think first of our neighbours. And our neighbour was not a relation or a tribesman, but any man in the world. The teaching was ineffective in practice in capitalist society because the whole motive power of human action was geared to economic self-interest. Within the new productive organisation, based on human co-operation and using the means provided by science, the teaching of Jesus can come into its own. Ethics, the pursuit of the good things, furnished nothing but insoluble conundrums in a class society where one man's good created another man's want.

In the new society it can be studied and practised at the same time.

The Needs of the Moment

If the full development of the new morality must await the new society, it is by no means a utopian morality. It would be a fatal error to assume that we must first form a perfect state before men themselves can be perfected. The essential features of the new morality are in fact growing up inside the forms of the old order just as they grew up among the revolutionaries in Czarist Russia. The war itself is already becoming a great transformer of morality. Individual self-seeking, so extolled in peace, has become a nuisance and is rapidly becoming a crime in war. In exhorting people to work together, to sacrifice themselves, to think and plan intelligently because the war demands it, a radical break is being made with the old morality and one which it will be difficult to reverse. It would be a complete illusion, however, to think that this change has yet come about; it took men years of revolution and hardship to bring it about in the Soviet Union. Nevertheless it is on its way now throughout the world, and the more clearly people see it and its implications the more rapidly and smoothly will it be accepted.

The struggles of the present time are the end-point of the whole sequence of earlier struggles and the start for new efforts. But understanding this will be of no use—indeed it will be no true understanding—if it does not march with the new activity needed for the immediate situation. To say that we are in the midst of the transformation towards a conscious society self-ordered for common good, is meaningless—even made untrue—in so far as we are not ourselves working to achieve that society. It will come only as a result of conscious, intelligent and co-operative effort by all of us.

At the moment the tasks before us are simple and clear. It is first of all necessary to destroy the forces that are openly trying to crush the new development. But it is not only necessary to work for the ultimate defeat of the fascist powers: they must be defeated at once, so that the material and human possibilities for the new world are not heavily compromised by the losses of the struggle.

Every month of inaction, of preparation for actions which

are continually put off into the future, means loss not only of materials for building a new world, but of the irreplaceable human beings on whom we are counting to build it. Every month lost increases the problems that will have to be faced later. It deepens hatreds and adds to the difficulties of achieving the willing collaboration that will be needed. It is no use thinking at this stage of the world conflict that by refraining from action now we may hope to preserve our own lives and possessions and let other people make the sacrifices. This view is even more foolish than it is contemptible; and yet, not reacting now, not participating in forcing the authorities to act, is equivalent to joining this tacit conspiracy of inaction.

The defeat of the Axis powers is not only an affair of the battlefield or even of the machine-shop; the enemies of the new world are not all on the other side of the Channel—they are among us and in us. The failures and defeats which have been suffered by the older democracies are not accidental. They are intrinsic to a system which belongs to an earlier age and cannot cope with the requirements of the present struggle. We must learn to understand and destroy the forces that belong to the past and are leading to defeat. There is no lack of courage; no lack of resignation and endurance; but they are neutralised by the effects of private greed and class interests and must overcome a widespread inactive apathy and frustration. The ruling class of this country did not go into the war to save democracy; they do not know what democracy is and if they did they would not like it. They went into the war to save their status, their pockets and their skins, and even in the war they have not forgotten that their position has to be secure, not only against the enemy, but against each other and against the common people. Hence the picture of protests against excess profits tax and coal rationing; the refusal to accept any effective and long-overdue social changes in wartime; the organisation of production to preserve peacetime interests; of the government controls of industry handed over to the biggest monopoly industrialists. Hence the important and dangerous confusion and delay in the production of war materials and in the full realisation of productive potential. Class-vested interests in the civil service and the fighting services have resulted in our slow and unadaptable response to modern fighting conditions on land, sea and in the air.

The whole strategy of the war as well as its tactics bears witness to this unready and laggard spirit. We have failed for eighteen months to assist the only ally that can resist and has resisted the Nazis. Ostensibly this is for tactical reasons; we are told we have been unprepared and we are still unprepared for a second front in Europe. The way things are going, and with the people we have directing them, there is no guarantee that we will not always be in this state. Men who do not know what they are fighting for, or who suspect that the ends of the war are not their ends, cannot and will not direct it effectively. They are not traitors: they do not willingly assist the enemy, but they will not press things unduly, they will not take risks, they will not demand the impossible, they will not ruthlessly dismiss and degrade those incompetent to deal with the problems of modern war; worst of all, they will not trust the people.

But the lukewarmness and inadequacy of the ruling class would not have been able to reduce us to the dangerous state we are now in if they had been balanced from the outset by the initiative and action of the great mass of the people, particularly of the working class. For years, the organised working classes, the Trade Unions and Labour Party, in this country as in the other older democracies, have tacitly accepted an inferior position. They have compounded with their rulers in consideration of receiving a slightly greater share of real goods and civic amenities. Social change was thought of as a gradual process by which the evils of the present would be removed without the necessity of violent action and with no discomfort to anybody. When the state of the world outside seemed to show increasingly the danger in which the whole of society stood, Labour leaders simply refused to consider it and surrendered even more of their powers to a ruling class which they were willing to believe would be able to defend them. All these attitudes were easy; they were impressed on the people by the whole propaganda mechanism of a modern commercialised state. But they were accepted by, and indeed almost violently forced on, the more conscious sections of the working class by the Labour and socialist leadership, more concerned with ingratiating themselves with capitalists than with securing the interests of their class and with it that of the whole people. One result of refusing to face the facts of the

situation was the loss of ability to think at all on social questions. Neither the people nor their leaders had any social philosophy, and the latter were even proud of the fact and spent what little intellectual energy they had in attacking Marxism, which presented the only coherent account of society and its changes.

The attitude of the years between the wars is still persisting through the war itself; it is an attitude which begins with apathy and ends with frustration. In the army, in the factories, men and women are conscious that things are not going well and that if it had not been for the Soviet Union they would now be feeling the consequences; but this knowledge, if it only leads to depression and pointless anger, will do no good. What is needed is action and not complaint. The people have the possibility of showing what they can do, not only in the endurance of calamity, for which their rulers are duly grateful to them, but in the achieving of victory by their own efforts and for their own good. The initiative now is with the people. It is for the people themselves—for the workers in the factories—to see that production is brought to its full pitch and expanded continuously: and for all, by every and any means to see that the politics, the diplomacy and the strategy of the country are woven together into an intelligent and forceful co-ordinated effort with the people of the Soviet Union and of the United Nations. It is not enough to have a great leader. We need leadership from below as well as from above; individual initiative, group initiative—all must find channels to make themselves felt effectively. Acceptance of a situation as grave as this is simply a lazy form of treachery. The will is there; the men and the ability are there; they are not yet sufficiently aware of their power or of their unity—but that is coming. Our problem is to see that it comes fast enough to meet the tide of enemy attack, to sweep it back . . . and then to start our great task of building a new and greater society.

From *Horizon*, 1942

BELIEF AND ACTION

Introduction

THIS is a time for endings and beginnings. The atom bomb may stand as its symbol of doom and promise. Never before in history has the world had such widespread misery, such fearsome apprehension and such great hope of escaping once and for all from the privations and violence of the past. The end of the war, the crushing of the fascist powers, the liberation of Europe and Eastern Asia, the discovery of a source of power incalculably greater than that man has controlled before, would seem enough great events for one year. But these events are only symptoms of something greater and more important that is happening to mankind. Man is becoming conscious for the first time of the possibility, as well as the necessity, of a conscious control of his world. We are at the beginning of a new era in which the people, at last firmly in power, can plan and act. Action implies belief. Man can only act efficiently on the basis of some accepted working picture of the world and of the place of man and society in it. But the old picture will not serve the new situation. The need for new lines of action makes it imperative to examine and to state the new beliefs that justify them and give them consistency and purpose.

The new beliefs are not an abstract, logical scheme to be imposed on men's minds. They arise out of old beliefs, though they are not mere variants of them. They first appeared in a few penetrating minds from the experiences of the earlier struggles against capitalism; they have spread and grown through the revolutionary and constructive experiences of the Soviet Union, of China and Spain, and many other countries. They are now burnt into the minds of millions throughout the world by the experiences of the war.

Experience and belief grow together. New beliefs, transformed from old ones by experience, are also verified by further experience and can become secure bases for action. This war, to the millions of soldiers, workers and intellectuals who have taken part in it, has been a war against the idea of treating men as machines and slaves in the hands of a leader or master race, and for a world which will realise the full possibilities of every

man, woman and child. The people of the world also know, from the experience of what went before the war, that although liberty and democracy must be secured, these ideals in themselves will not be enough; there must as well be a drive to secure good living and peace for all. Future wars must be prevented. The atom bomb could produce anywhere in a few days desolation far worse than war produced in Germany. There will be no good living conditions without well-organised industry and agriculture, no health or economic security without a state medical and a state employment system. The acceptance of these conditions for organised action marks a radical break from the pure liberal philosophy of western Europe, a philosophy that first grew up for a society of tradesmen and farmers. It does not, however, mean the discarding of the ideals of that philosophy. Planning is not incompatible with liberty, much as those who hate both would like us to think so. The key to the integration of old beliefs and new conditions is to be found in the philosophy of Marx, Lenin and Stalin. Their intellectual basis is the combination of social analysis and the new knowledge of the world of matter and life that has come from the revolutionary advances of the natural sciences.

These beliefs are solidly materialist, but they are none the less humanist. The social evolution of man is not limited to economic and political forms; it includes the whole of culture and philosophy. Millions of people, far more than are consciously aware of it, already accept them partially or wholly. The attempt to state them here in a small compass will serve its purpose if it shows—better perhaps than the volumes or libraries that would be needed to expound them fully—how coherent they are and how they may well serve the needs of the new times.

The argument can be summed up in the most direct manner in six theses:

1. The most important job in the world today is to ensure that all human beings have a chance of full development.

2. This can be done only by a conscious, organised effort under the direction of the people themselves. The majority of the people can be trusted; no superior or élite groups can be.

3. The material and social conditions necessary for the realisation of human possibilities can be achieved only through a well-organised productive and distributive system. This

implies the continuous raising of the standard of life, particularly for all depressed classes and races, brought about by scientific research and its applications.

4. A new outlook and transformation of values is needed to effect these changes. The new values must incorporate the old tradition, but also bring it into relation with present needs. The essentially immoral influence of capitalist individualism must be replaced by a morality which emphasises intelligent working together for common good.

5. Art and culture should become a common living heritage actively shared in by all and not a dead achievement to be admired by a selected few. Philosophy must cease to be a refuge of reaction and mysticism and become an active expression of human understanding of the world and of human ability to change it.

6. Beliefs and attitudes must be concretely related to the solution of the problems of the new era; to the final eradication of fascism and to the assurance of peace and democracy. A large measure of collaboration between people of different political and economic opinions will be necessary. The achievement of this collaboration will be easier the more people come to understand the operation of social forces in the ways exemplified in the theories and the practice of Marx, of Lenin and of Stalin.

1. *Man is the Measure of All Things*

Both in belief and in action a Marxist is a humanist, he lives by human values achieved through human action. This humanism is not however as in the past based on a mystical feeling of man's affinity with the gods, or on the belief that the whole world has been created and maintained as a stage for man's salvation. We value man more now because we know more. Man's character and man's achievement become greater and not less when viewed objectively and scientifically. The old idea that man was the centre of a universe created for his especial benefit, though wrong as a physical statement, is right in intention; it is equivalent to the present view of human society as the one growing point of universal development. But man is no longer an example of a universal type, an image of his "creator." He is a component—a product and at

the same time a producer of a complex developing and ever more conscious society. The centre of human interest and of human action lies in that society and its development. Because an individual man is a product of society, he needs must incorporate in himself, in behaviour and belief, to the degree in which he is educated, all the traditions and history of that society. This in itself makes him of a different order of existence from any animal. Animals inherit in their bodies the cumulative results of organic evolution. In man this bodily inheritance is only a foundation, his distinctive personality is a social inheritance. "Organisms are born; man is made."

But society is not a fixed order; every man's life adds to it and changes it. Every man is a maker, a poet. "The grass groweth up; in the morning it flourisheth and groweth up, in the evening it is cut down and withereth." Not so man. No life passes but that something is contributed to the common inheritance. Every human life influences others. The lives of companions and children are consciously or unconsciously, directly or indirectly, changed by it. The pattern of the future society is the product of all such changes.

This makes it both wrong and stupid to treat any man as a machine or part of a machine. The respect for human individuality and human capacity finds its logical basis in the understanding of society and its transformations, given us by Marxism. Respect for the individual man can of course also be reached emotionally and is imbedded in the framework of all great religions. Only too often however has the assertion of the uniqueness and sanctity of the individual been used as an excuse to degrade men and to deprive them of education, opportunity and democratic rights. To respect human individuality does not mean such pious acceptance of present conditions of human life. What any man is now is only a small fraction of what he might be if his powers could find direction and scope. Human potential is enormous; we cannot know how great it is—that can only be found out by allowing it to develop itself. The greatest crime in the world is not the denial of food and shelter to the human animal, but depriving man of his inheritance of thought and the possibility of full and constructive expression of it.

Human potential can only be realised in and through society. The balance between society and the individuals

composing it is only now coming into human consciousness. Too great an insistence on individuality means an anarchy in which the material conditions necessary for the realisation of full human possibilities cannot be achieved. Too little insistence on it means a tyranny in which the individual is limited to a particular function and in which, by demeaning man, the purpose of the organisation itself is frustrated. The maintenance of the balance between these extremes is the greatest of responsibilities. It is too great to be borne by individuals; it is the responsibility of the people.

2. *Government of the People, by the People, for the People*

Belief in the people follows from the understanding of the importance of man in society and of the evolutions of that society. This belief is no more mystical and vague than the equivalent statement of the importance of man. Isolated man is a fiction, man carries society inside himself, therefore there can be no better criterion for understanding, value or action, than in the collective judgment of the people. Ideally, in a equalitarian, communist society, that judgment will be freely expressed. In our present class-divided societies it is more difficult to discover but it is there; it finds expression more in action than in words. The forms of accepted belief may often be traditional, may represent the choice of a dead society; but they are tacitly modified in action in closer accordance with the realities of the moment. The people may err, and err gravely and fundamentally just as the individual man may suffer from lack of judgment or delusion; the miseducation inevitable in a class society, whether or not it is deliberate, may warp judgment for a while but unlike the case of the individual man there are limits to the degree to which the whole of the people can be deceived in the interests of a few. Their experience will in the end be too different from what they have been led to expect and disillusions will lead to a new understanding. Over and over again, and never more than in these last years, the common feelings of justice, fellowship and liberty have reasserted themselves in the breakdown of oppressive systems. A selected élite may come to delude themselves for a while in their superiority to the common herd, but the repressed consciousness of their loss of community and the unfairness of their position

always turns them to futility and madness. The fable of Antaeus as Stalin drew it, a giant whose strength came from the earth, is profoundly true. No man or party can separate himself or itself from the people and live. In this sense, democracy has an absolute value; but democracy must be total, covering both the economic and political fields, and also sufficiently wide-spread so that every member of society can take an active part in it. "Every cook must learn to rule the state."

Democracy is by no means a simple idea. It is today the most abused of words, its different meanings being flung across the conference table in the attack and defence of very different systems of government and as a cloak for interests that have little in common with it. There are real differences such as those between established democracy and democracy of transition. Our British democracy, from long practice, does enable us to secure the people's will without coercion or bloodshed, but clumsily, far too slowly and with a heavy bias on ancient privilege. In countries with a long history of tyranny and feud such democracy is unrealisable. All attempts to reproduce its forms, especially the giving of full freedom to the representatives of wealth and reaction, fatally impede the rapid and drastic decision to rebuild industry and agriculture on which the very lives of the people depend.

3. *Planned Abundance*

Belief in man and in the people expresses itself concretely in the struggle for better human and social conditions. Individual human capacity can only be realised, collective human activities can only be carried out, if the material and intellectual conditions are suitable. They are not so at present. But now we know enough of what is wrong to set about putting it right. What we have to do is to mobilise the material and human resources of the world in a way which capitalism has never been able to do. Even in the most populous and already industrialised countries there is everywhere insufficient education, insufficient scope for abilities; above all there is the taint of the profit motive which prevents the majority from even trying to give of their best. The war has shown how this can be altered under the most unfavourable material conditions, once there is a common accepted purpose. The war will be

effectively won only when the common purpose is made permanent and is turned from the defence of old civilisation to the achievement of a new and better one.

The most immediate task is the restoration of devastated Europe; the peoples are liberated, they have the will and, in great measure the ability, not only to restore what has been destroyed, but to build something much better in its place. At the moment they lack food, fuel and machinery; we must see to it that they get all these before starvation and disorganisation have seriously weakened their capacity for recovery.

Scarcely less urgent is the situation of the great populations of Asia and the tropics. Some thousand millions there are on the edge of starvation. Most of these are afflicted by preventable diseases, and lack all the mechanical resources which have been developed in the past two hundred years. They have little or no education, are deprived of political rights, and are economically exploited. As things are today, at least 90 per cent of the human race have no chance of developing their potentialities as human beings.

It used to be urged that all this was inevitable; that, on account of climate and race, the natives of Asia and Africa were inherently unadaptable to western civilisation. Now, in the light both of the Soviet Union's experiences in the last thirty years and of many other parts of the world during the war, everybody can see what pernicious nonsense this view was. The undeveloped parts of the world contain a waste of human capacity and a mass of human suffering that call out for instant remedy. And the remedy is clear and simple. It is the organisation of both agricultural and industrial production, planned so as to provide the known needs of the people from known natural resources, by the aid of and soon under the direction of the people of the countries themselves. The more advanced countries will have to provide capital goods and instruction as was done by the Russian Republics in Soviet Central Asia. Within a generation, however, the people themselves should be able to take over and make increasing and independent contributions, both material and cultural, to the world at large.

To realise the existing potential human resources of the whole world is elementary justice, but it is equally important to raise that potential by a steady improvement and rationalisa-

tion of the processes of production. Physical and biological sciences, technology and economics, must be welded together in an increasingly conscious way to provide a productive organisation yielding the maximum return with the minimum of monotonous or dangerous labour. We know from the experiences of the Soviet Union that this is a perfectly feasible aim, but to realise it under a capitalist economy, with its tendency to turn more and more to monopoly and restriction, is a difficult but not impossible task. Even the capitalist system, however, can be made to organise production rationally, with due regard to the human factor, in times of war. With the same controls it can be made to do so in peace, pending its reorganisation on more rational lines.

The advent of atomic power has removed once and for all any limitation on the material resources at man's disposal. We should have, in a few years' time, means to feed and to supply the whole population of the world at the highest present level of consumption. But this cannot be achieved unless we can dispel the secrecy and suspicion that the atom bomb has brought, and unless we can, on an international scale, put an unprecedented effort into research and development.

It can be done. The single and steady purpose, the unity of the people, the willingness to go all out and put up with every danger and discomfort that marked the peoples at war must not be lost in peace. There are new and real wars to be fought; for health, for knowledge, for the realisation of the human potential—wars against disease and hunger, wars against obscurantism and reaction. These are not metaphors. Such wars can be fought effectively; not, as in the past, solely by devoted individuals, piecemeal, but by bodies of men organised and planned. They will be backed by the material resources with which we fought fascism; the laboratories, the factories, the ships, the bulldozers, the food and drugs and they will canalise in their service the same unity, enthusiasm and devotion.

4. *Transformation of Values*

The continuation of capitalism is conditioned by its economic and political power, but it maintains this very largely through the prevalence of false beliefs. The original ideology of capitalism—material self-seeking and a salvation, other-world religion

—was in its time a liberation from the more restrictive ideology of feudal Europe. The advance of science and technology however has revealed it to be as untrue in fact as it has become antisocial in tendency. We do not know the whole truth about the universe and society—the essence of science is that we are always finding out more—but we do know what is nonsense and we should be more courageous in stating it. Much of liberal, capitalist ideology, particularly its economic, political and religious aspects, is demonstrably false. It needs to be transformed so as to bring it into line with our present knowledge of natural and social science and converted into an ideology adequate for a consciously directed human society. Not to do so would be to allow it to degenerate into a mystical, anti-rational fascist ideology.

Ideologies are not transformed so much by argument as by experience and action; however objectively false a religious belief may be, if it provides emotional satisfaction and ethical justification it cannot be destroyed unless people find for themselves something to live for more fully than they could before. Piety, ignorance, economic and political ineffectiveness go together and need to be destroyed together.

Religion in the past has, at its best, represented communal human aspirations based on all that could be known of the world and of man; at its worst, as in Imperial Rome or in the decay of capitalism in our time, it may become an organisation to maintain social tranquillity in an unjust system on the basis of emotional religious experiences and intellectually untenable beliefs. In a society where social injustice no longer rules, religion may well find again its roots in honest human feeling and incorporate the new knowledge of the natural and social sciences. The religion of submission to higher and inscrutable forces, with its implied other-worldliness and acceptance of existing evils, is to be replaced by collective pride and individual achievement in a task which is regarded as a common human effort for human ends. In this, people can retain that deep sense of community and human brotherhood and the duty and enjoyment of mutual help and betterment which is charity.

History and tradition should be powerful allies; when things changed slowly and memories were short, tradition served to preserve things as they were and as it was thought they had always been. Now we are in the midst of the most rapid and

world-wide changes that humanity has ever experienced. tradition can no longer be followed blindly; the material framework in which it operates is everywhere breaking down. Nevertheless, once we understand their nature, history and tradition can become accelerators and not brakes. We are leaving behind a history of dynasties and battles and are coming to see the whole picture of human social development from the first small scattered societies to the conscious, integrated scientific world-society of today as one continuous though dialectical process. A strong people, as the Soviet Union has been showing us, can make its past live—however different from its present—and draw strength and unity from it. We all have our history to help us, nationally in each country, culturally for western Europe or India or China, in common for the whole world. History can at the same time help us to see how changes can be brought about and help us to feel ourselves, in the making of the history of today, as a link between the people who came before us and those who will come after us. Techniques and social forms change, but a common humanity that can be felt as well as known runs through the whole of recorded or discoverable history from the obscure past to the unknown future.

The new phase of world history which we are now entering calls for new men and new virtues; much of what now stands for virtue and morality belongs to the era of capitalist individualism. We are only beginning to realise how far the social vices of capitalism had penetrated the attitudes and moralities, not only of the bourgeoisie, but of the working class itself. Capitalist class society was in itself so fundamentally immoral because it made the status and relations of men dependent on inheriting or making money instead of on their ability to serve the community, and because it actively prevented the expression of fellowship between men and men. This was corruption, however masked by legal forms created in the interests of property-owners seeking to preserve their wealth. The bourgeoisie in some countries has come to tolerate almost any perversion of justice to protect their own position, up to the full horrors of fascism. In the working class there was a double evil; some of the most able, seeking a decent material basis for life, were drawn away into the bourgeoisie; the rest were frightened into a cynical acquiescence by the fear of losing

what they had and became so used to accept an unjust inferiority that they could not realise their own power. Because of the class system, the great majority were forced to turn away from things that most concerned them—the possibilities for making a good life for all—to trivial and narrow fears and pleasures.

The immorality of the system was intellectual as well as material and social. Because the system would not stand honest examination, education was warped to prevent any serious study of it. Every child's birthright is the knowledge of the structure and meaning of the society to which he will contribute his life's work. But that knowledge has been deliberately withheld from the education of the people at large and was only permitted to the selected few at the universities in a deliberately distorted form. There is still no provision in schools or universities for the teaching of professed critics of the capitalist system.

When the system itself is basically immoral, it is impossible to build any decent morality which does not attack it. A radical change in morality is in any case required by the new social relations which men are already entering into in an organised and planned society. The relative importance of different virtues is bound to be affected. Old virtues may even appear as vices and new virtues instituted. Many of the basic virtues—truthfulness and good fellowship—are of course as old as humanity and need no changing, but those based on excessive concern with individual rectitude need reorienting in the direction of social responsibility. Altogether new virtues must be added. These are implied in the recognition that a man is not simply the possessor of an immortal soul who will be judged in an after-life on the basis of his following a certain set of rules in this, but is one member of a changing community with a vast task in front of it. His life, mental as well as material, comes from the community and goes on with it. To fulfil it, it needs to be given freely in its service.

Ignorance and innocence are no longer the proofs of sanctity. A man must know and understand the aims of society and the mechanism of society if he is to be effective in playing his part. This is no question of a blind and obedient carrying out of orders; that is fascism and the "Fuehrer princip." Each one is called upon to understand, to accept and to use his initiative

in the furthering of the common aim which he has himself taken part in forming.

The change from individual to collective morality corresponds to the realisation of the relative ineffectiveness of isolated individual action under modern conditions. If in the last century a man was struck by the misery and ignorance of the natives in Central Africa, he went out there as a medical missionary; today he would realise that the health and wealth of the African people is a political and economic problem to be solved by joint action with the African people and the workers and progressives in Britain. We now realise that piecemeal changes not only fail to achieve a general improvement, but actually retard it by diverting effort and by giving a delusive impression that something is being done. Because collective action in the industrial and political field is the only effective action, it is the only virtuous action.

5. *Towards a Living Culture*

The building of a world free from disease, ignorance and wearing toil, in which the physical necessities of life have become everyone's birthright, is a practical material aim. It is also a social and spiritual aim. Until we have it the full realisation of human mental and social possibilities cannot be achieved, and unless we are working for it all human effort in the field of art or morals is poisoned at the roots. But the fact that we have a material aim does not mean that these other aspects of life are not considered or are to be neglected in the interim. The pursuit of art or scholarship has often been urged as a justification—or at least an extenuation—of a system that, it is claimed, has made this possible. If we could only attend to the things of the spirit, the apologists for capitalism maintain, we would not find mere material things so distressing. Art and learning, like religion, are held up as things beyond and apart from the economic and social system. History shows this to be palpably false. The arts and humanities of the different epochs grow plainly out of the conditions of those times as Vico had already shown over two hundred years ago.

The forms of art—painting, literature, drama, poetry, music—are all expressions of the impact of society on individual human beings. They achieve the purpose of their makers in so

far as they stir and express the feelings and aspirations of the less articulate members of that society. A great work of art may do more; drawing from social roots it may produce a combination of forms or ideas that is absolutely new, but can, once established, be taken up and further developed by others. It is in this sense that art is creative. A work of art belongs to its time and is produced in the language of its time, but it may contain such a strong appeal to feelings common to all societies that its message reaches beyond its own time. That is the criterion of great art. The values that the artists express are social values, the relations of men to each other, the relations of men to nature; nature itself has beauty and meaning in so far as it is perceived and worked upon by man. Even the beauty of wild nature was first appreciated only in contrast with that of town and field. The poets absorb unconsciously, but often consciously as well, the social strivings and intellectual achievements of their times and fix them so that they move the feelings as well as the minds of men. If we can help to make a live and positive society which is successfully achieving better material conditions for all, its arts and humanities will look after themselves. It may take time to find the appropriate means of expression. We have only past forms to go on, and past forms will need many modifications before they fit.

Science and scholarship can adapt more quickly. It is, after all, the work of science and education that has brought about both the knowledge of the physical needs of men and the means of satisfying them. The scientist has done this partly directly but even more indirectly by finding the multiple relations that underlie the behaviour of material systems, living and non-living, and using the knowledge of those relations to control them. But the scientist now realises that what has gone before in the history of science are only the first easy steps; steps that could be taken with simple ideas and simple apparatus by men working in isolation or in loose societies. To get to the bottom of real basic problems of physics or biology we now need team-work on a large scale, with far more scientists and full popular appreciation of the meaning and value of science. It is a stupid and wilful misunderstanding to suggest that this will mean the neglect of fundamental science. All those who have worked in applied science realise how absolutely essential it is that fundamental science should be pursued but also how much

fundamental science has to gain in the new problems and the new techniques derived from applied science. Human culture is not a sickly plant which can only be kept alive by preserving the artificial conditions in which it is cultivated today, still less by a futile attempt to recreate the conditions of former times. It is a stunted plant which will only grow to its full stature when the latent abilities of all men can be realised in the new society.

Every great age in human history had its characteristic culture; a pattern of thinking and acting which was basically acceptable to the people of that time. The period out of which we are just passing was no exception. The liberal individualistic, almost atomic, philosophy started in the Renaissance and grew to full stature with the French Revolution. It is a philosophy of the "rights of man," of "liberty, equality and fraternity," of private property, free enterprise and free trade. We have known it in such a debased form, so unrelated to the pattern of the needs of the times, that only lip-service is paid to it, and honest but ignorant minds have preferred even the bestialities of fascism to its unreal and useless tenets. Liberal philosophy was not only political—it stretched over the whole field of the intellect; it was the creed of the pure scientist, the scholar, the artist and the genius, each working by himself as he thought fit, but all contributing as surely as the individual trader or the individual manufacturer to that mysterious but perfectly natural process—the greatest good for the greatest number.

That philosophy is now discredited. Whilst recognising the greatness of its achievements, we also recognise that that way of doing things is finished. To try to perpetuate it is to tie down the present to the past. The achievements of liberal philosophy have themselves been incorporated in the new dialectical materialism of Marx and Engels which consciously and often unconsciously is coming to be generally accepted as a basis of thought. It is not the isolation of men but their increasingly conscious co-operation that now needs to be stressed. Dialectical materialism is a philosophy of unity, of interdependence of parts rather than their isolation; it is a philosophy which unites thought and action, analysis and synthesis. It is pre-eminently appropriate to our times, since it is a philosophy of struggle which is thought of as the only way in which new things and processes occur. It is far more a programme of thought and

action than it is a system of philosophy in the old sense. In the light of Marxism, many subjects thought to be dull or even closed take on a new significance and acquire new interest. History ceases to be a meaningless chronicle and becomes a field of interplay of economic and social forces which lights our future as well as our past. Biology becomes unified and the phenomena of life are associated on the one hand with their own evolutionary history, and on the other with the present satisfaction of men's needs. Physics, chemistry and even mathematics lose their absolute and unchangeable character and are seen as indissolubly linked with the nature and origin of the universe. Nothing is lost of the invaluable and reliable methods which the exact sciences provide, and much is added to them. Dialectical materialism provides a method of finding out where we are going rather than of verifying the exact spot when we have got there—that remains in the sphere of the natural sciences. The great value of dialectical materialism is in helping to sum up and to comprehend the whole of knowledge in such terms as it can use for successful action here and now. It gives a scale of various developmental levels of the universe which shows us the overriding importance of society and of man, who makes it and is made by it. It is here and now, in the politics and economics of human society, that the decisive events of all time and space are occurring. Man recovers his own importance in the world scheme first conceded by religion, then denied by the materialism that came with the birth of science.

With that new picture comes new responsibility. Men individually must understand and collectively must work together to realise the possibilities that live within them.

6. *The Test of Action*

Belief implies action. The tests of how well we have understood the workings of the universe and of society is how competently we can chart a course of future human development and maintain a conscious control over it. That is the basic difference between our present times and all that went before. What began as an idea in the minds of Marx and Engels under the experiences of the turbulent rise of capitalism, what was tested in action in the Soviet Union by Lenin and Stalin for

the past thirty years, has now become a world-wide phenomenon. Man has willy-nilly to control his material and social economy as one organised whole.

That responsibility has already been grasped. The one final attempt to reverse this process and to rob men of their heritage of knowledge and power has been crushed in the war by the united efforts of the people of the Soviet Union and those of Europe and America. The lesson has been a terrible one. The unparalleled suffering and destruction of our time is the penalty that has had to be paid for the hold that reactionary ideas have had in capitalist countries and the inability to break away from them in time. But the lesson has been learned, the war has been won, and the world is about to enter the hard but glorious period of recovery and reconstruction. This time there is no mistaking the people's purpose. Everywhere in Europe, and, most important of all, in Britain, elections have shown that the great majority are determined to control the forces which science and technology have provided and to use them for the common good and not for private profit, for peace and not for war.

That determination in itself is an enormous step forward, but it only marks the beginning of new struggles. By assuming responsibility for control, the popular forces have to meet the enormous physical and organisational problems of repairing the damage of war and bringing order out of the chaos of capitalist production. Everything that can be represented as a mistake will be used by the forces of reaction to weaken the people's faith in themselves and to cause disunion among the popular forces. This will be as true in the international as in the national field. The great alliance of the United Nations which has been achieved through the bitter needs of the war has now become even more important as a guarantee against future wars which might be far worse than that through which we have passed. To maintain that alliance and to guard it against its open enemies and the more subtle disseminators of mutual suspicion will require constant vigilance and continued efforts to reach ever closer understanding. Lack of confidence, confusion, suspicion—all derive from ignorance. The fuller and more comprehensive our knowledge of social forces, the more easily can these be exposed and counteracted. Knowledge is not academic; we have behind us the experience of

war organisation in the forces and factories, an experience which has brought us in Britain much closer to the longer and even more dearly won experiences of the Soviet Union. To the degree to which we can see things in the same light can we go forward together in fellowship and hope.

From *Modern Quarterly*, Winter 1945

THE CHALLENGE OF OUR TIME

The Social Responsibility of Science

A CHALLENGE is something to be taken up, not something to be bemoaned and evaded. If today we have to face greater dangers and disasters than ever before in human history, it is also today that we have far greater possibilities and greater hopes. We cannot leave this challenge to be taken up by soured intellectuals with their eyes fixed on the past. It must be taken up by those who have the hope, the knowledge, the ability and the drive to define the problems of our time and to solve them. We will throw off our anxieties and quell our fears not through any metaphysical searchings of heart but by getting down to the urgent practical job of securing the conditions for a good life for all the people of the world.

Now this is the first time in human history that men have had the knowledge and with it the power to tackle this job. That is why the crisis of our time is something new and different from any of the crises of the past. What is new is that science has now come of age. Before, it could explain things, help to make useful machines and gadgets, advise here and there; now it has become the dominating feature of our time. This did not happen all at once. It started four-hundred-odd years ago when men began to break away from the agelong habits of village and small-town life by combining book-learning and handicraft to lighten their toil and enlarge their powers. Ever since the time of Newton the movement of science and invention has run on with increasing impetus through the industrial revolution to the dawn of the atomic age. The harnessing of

nuclear energy—the energy of the sun and stars—to men's needs is the greatest conquest they have ever made, far greater than agriculture or fire or steam; but great as it is, it is only a symbol of what men can do, and know they can do, in all fields of endeavour. The methods of organised research and development which have grown over many years and were tried out and perfected during the war have put in our hands powers which are literally unlimited.

The major fact we must now face is that with these powers man must now for the first time accept the responsibility for running his own world in a sensible way. It is especially the scientist's responsibility because he is the first to see what can be done, but it is none the less everyone's responsibility. It is understandable that for some people this responsibility is too terrible to face. They would prefer to turn back to old ways, to the ages of faith and custom. But whether we like it or not, there is now no turning back. The dangers of the world today and tomorrow are no longer the dangers of time and chance, but those of failing to control and to direct wisely the conscious efforts of organised human beings. We have now one world: we must see how to run it. For hundreds and thousands of years, it is true, it has run itself—piecemeal. There was a basic customary life of village and town which continual wars, pestilences and famines could disturb but not destroy. Seed-time and harvest, hearth and home, were more important during all those years than kings or warriors, philosophers or saints. Now all that has gone and gone for good. The world won't run itself any more. It is for us to think out afresh what kind of world we want and how we are going to get it.

In this task we have before us the example of the Soviet Union, where the first efforts towards a rational communal plan were made. That example inspires the world today, even those who would repudiate the inspiration. It underlies our plans in this country for industry and agriculture, it will underlie the future organisation of world production and world trade.

Now there are some people who would like you to believe that once you start trying to run the world in a sensible and conscious way, something terrible will happen to human values, that men will be considered only as machines, that human society will be reduced to that of the white—why not

red?—ants. This is sheer nonsense. In fact it is the other way round. It was the thoughtless and blind pursuit of profit that led to the mechanised horrors of the industrial revolution and the tropical plantations. The running of the world in a conscious way is going to be such an enormous and complicated job that we shall need to make use of every scrap of intelligence, every scrap of goodwill, every scrap of initiative that every person in the world possesses. The position of the individual in the new world is going to be far more important and interesting than it ever was in the old, and the way individuals work together will be something far more democratic than anything we have known.

Voluntary Co-operation, not Dictation

Of course, none of this will happen of itself: it is happening now because of the common will of men derived from their experiences of the recent struggles and from their knowledge of the new powers that science can bring. The job of providing enough food, housing and general consumer goods for all the two thousand million inhabitants of the world is a big, practical job, but we know it is technically possible and we have a pretty good idea of how to carry it out administratively. It cannot be done by dictation; it will have to be done through the integrated and voluntary co-operation of hundreds and thousands of small groups of people working together in their farms and factories and communication services.

No doubt there will be some who from ignorance or spite will stand in the way rather than help, just as the Malignants stood in the way of the Commonwealth of three hundred years ago. But their opposition cannot hold up this great transformation that comes as a natural consequence of the increase of human knowledge and power.

The scientists who have given thought to their social responsibilities are fully aware of these problems. Science is not something limited to electrons, chemicals and machines; it ranges over the whole field of living creatures and it is now coming more and more to deal with human beings in their social and economic relations. Thousands of scientists, in production and in operational research, have had concrete experience in dealing with them during the war. The scientist

is thus the man least likely to underrate the importance of the individual and the need for the democratic working of society. Let me quote, in proof, from the argument of my article in the *Modern Quarterly*, which Mr. Koestler would like you to believe is a new bible of Belsen:[1]

> I. The most important job in the world today is to ensure that all human beings have a chance of full development.
>
> II. This can be done only by a conscious, organised effort under the direction of the people themselves. The majority of the people can be trusted: no superior or élite groups can be.
>
> III. The material and social conditions necessary for the realisation of human possibilities can be achieved only through a well-organised productive and distributive system. This implies the continuous raising, through scientific research and improved organisation, of the standard of life, particularly for all depressed classes and races.
>
> IV. A new outlook and transformation of values is needed to effect these changes. The new values must incorporate the old tradition but also bring it into relation with present needs. The essentially immoral influence of capitalist individualism must be replaced by a morality which emphasises intelligent working together for the common good.
>
> V. Art and culture should become a common living heritage actively shared in by all and not a dead achievement to be admired by a selected few. Philosophy must cease to be a refuge of reaction and mysticism and become an active expression of human understanding of the world and of our ability to change it.
>
> VI. Beliefs and attitudes must be concretely related to the solution of the problems of the new era: to the final eradication of fascism and to the assurance of peace and democracy. A large measure of collaboration between people of different poitical and economic opinions will be necessary. The achievement of this collaboration will be easier the more people come to understand the operation of social forces in the ways exemplified in the theories of Marx and the practice of Lenin and Stalin.

The morality I have there advocated bears no resemblance to Mr. Koestler's caricature. It does not mean blind obedience to a nation or party. It does mean a recognition of what is now a plain fact, that, as the Bible has it, "we are all now members one of another," and we must all participate consciously and willingly in the framing and carrying out of common policy rather than in seeking our own personal success or salvation. In the new world everyone has the responsibility, not only of doing well in his own job, but of

[1] Broadcast "Challenge of our Time" Series, *Listener*, 21st March 1946.

seeing where and how his job fits in with collective human effort. He must be an organiser as well as a worker. As Lenin said, "Every cook must learn to rule the state."

The dilemma between means and ends that Mr. Koestler puts before us is unreal and delusive. The scientist knows that the achievement of any human purpose is a unitary thing; in planning it there is no separation of means and ends. The lives, health and happiness of the people working in a factory are as much part of its planned production as the finished goods it sends out. Of course we don't know all the consequences of our actions but our job is to make as good provision as we can for everything we can foresee, to keep the plan flexible to cope with unforeseen complications and to learn by our mistakes. The danger lies not in clear-cut and conscious action but in pious and cowardly refusing to act, in continuing to muddle through in the old way. Many times more people have died and suffered from avoidable famine and disease due to selfish ignorance and inaction than have ever been killed or wounded in all the wars in history. Action may be wrong sometimes; inaction in the face of evil is always wrong.

Those who foster the fear of using our powers are doing the gravest disservice to humanity; for fear paralyses generous action and creates suspicion and still more fears. There is one fear that is with us now which is holding up everything constructive in the world—the fear of war. Why? Compare our position now with what it was ten years ago. Then we had before us the growing perils of the armed might of fascism, and behind it the poisonous doctrines of race-hatred and the tortures of the concentration-camps. That force is now smashed, and its ideas are only effective in the minds of those in the victorious countries who were never really opposed to them. What are we afraid of now? The atom bomb, of course: this horrible new product of science which multiplies the destruction of which we have had a small foretaste in our blitzed towns. But the atom bomb does not make itself or blow itself up. The real danger lies in the creation of a world situation which might allow and even force statesmen to order its use. And why is there this danger? Because, we are told, of the attitude of the Soviet Union: the people who, by the sacrifice of twenty million of their brothers and sisters, saved us from any commensurate sacrifice: the people now bent on

repairing destruction of which we in this country have but a faint experience.

We are afraid of another war which can only occur if we deliberately sabotage the effective international collaboration of which the United Nations Organisation is the first embodiment. The real danger does not come from the Soviet Union, or the atom bomb, or from the inherent wickedness of man, or from our intrinsic inability to co-operate in building a new world based on common effort for common good. It comes from those who do not want this kind of world: those who talk of wars and rumours of wars: those who have discovered the special values of "western civilisation," the defence of which we can now take up from the defeated Germans. These are the enemies of promise: these are the real heirs of the Nazis. Unless we can stop them splitting the world into two camps in men's minds, the fatal division will grow and war will be inevitable.

Maintaining Peace

We know that if, and only if, we can maintain peace, shall we be able to use the new powers to give us a far better and freer world than we have ever known. This we can do by showing our sympathy and support for all the constructive work that is being carried out in the world today. We can maintain peace by thinking less about the old British and imperial interests that have done so much to enslave and bedevil the world in the past, and more about the constructive work that is going on in the world today. The movements that grew up with the Resistance, the movements of the common people, are trying to repair the ravages of war, to use the resources of their countries for a fuller life for their people. These are the forces we should be supporting instead of hindering. Above all, we have to keep the friendship of the Soviet Union that we held in the war, and show that this is our will and intention by acts and not by words. If we can do this, the fear that hangs over the world will be lifted, and the work that has to be done can be started with full hope of success.

Already in this country we have begun to make a decent, ordered, human world. With social security, with a national health service, with new education, with new planned towns and factories and mines, we have something to look forward

to, and if we preserve peace as well that work can go on to the greater task of raising the standard of living of India, China and the rest of the world.

Pay no attention to those who want to put a brake on progress and who try to distract you from these tasks by preaching despair and suspicion. Leave them to their own futility and spite. We want faith, not to endure disaster, but to avert it and to build anew. Where are plenty of us in this country who have this faith already and plenty more who will get it. We will find, in the old words of Cromwell, "men who know what they fight for and love what they know."

Broadcast, "Challenge of our Time" Series, 31st March 1946

THE RELEVANCE OF SCIENCE

INTRODUCTION

THE six essays in this section were written over a very long stretch of time—1928 to 1947. They are concerned primarily with the inner significance of science and its relation to philosophy and religion. The clear contradiction which seemed to exist in the nineteenth century between science and religion was replaced in the twentieth by a large blurring of the issues; on one side the scientists, especially the more eminent, were frightened by the events of the time, particularly by the Russian revolution, out of adopting irreligious views, and on the other the clerics found that science was not so dangerous after all. The result was an attempt to create in the popular mind a general impression of uncertainty and mysticism inside science itself. It was to counteract this tendency and to show how the concrete and positive advances of science in the century were far more important than quibbles about their metaphysical meaning, that most of the essays in this section were written. At the same time they attempt to show the close links between the development of science and that of other aspects of human activity, both political, in relation to democracy and liberty, and economic. They express various aspects of the general problem which was treated in my book *The Social Function of Science.*

THE IRRELEVANCE OF SCIENTIFIC THEORY

SOME half-century after its practical achievements were recognised the dogma of science is rapidly becoming respectable. The Archbishop of Canterbury benignly presides over the Royal Society dinners, and there are few philosophers, even at Oxford, who will entirely exclude modern scientific theories from their philosophic systems. Yet this change does not represent—we are constantly told—the triumph of science over

its dogmatic enemies. It is rather that science itself has changed, has become suaver, more refined, less materialistic, has admitted from its own intrinsic discoveries that the universe is a far more metaphysical place than it was thought to be fifty years ago. This harmony of scientific, humanistic and religious thought is a most agreeable picture in comparison with the discords of the last century.

There have been many periods and many cultures where as good agreement between different lines of thought has been reached: in mediaeval or Chinese scholasticism the process had even advanced further to the systematisation of the ideas to which every educated man would assent and in which science, philosophy and religion were inextricably woven. These periods have been preceded and succeeded by periods of dispute so much more violent than the nineteenth century that people would kill others or die themselves for opinions. Now it might be thought that these alternations could be explained by supposing that where philosophic or religious thought—either subserviently or by superior intuition—arrived at conclusions which were in accord with the concrete scientific knowledge of the day, there would be harmony; and where for reasons of stupidity or traditionalism it refused to do this, there would be conflict. But this view and its converse from the religious point of view is much too simple to fit the facts: it is more in the nature of a statement of the problem than an explanation of it. It is not only in the primitive stages of human society that religion and science were inextricably confused in magic: the same interdependence has remained ever since, cloaked in the more advanced stages by a terminology which serves to separate them in appearance. The real conflicts lie between groups of ideas vitally affecting man's emotional life. One set of these may at any time find more support in external phenomena than the other. At such a time that group will represent science and the other religion or philosophy, but the same ideas may be advanced at different times on totally different bases. For instance, the idea of an absolutely impersonal universe completely determined by ineluctable law is common to primitive Buddhism, Stoicism and Materialist Determinism; but the means of establishing it were in the first place purely mystical, in the last scientific, while in the case of the Stoics it contains a mixture of both elements. All must have given a somewhat

similar satisfaction to their adherents, all led without apparent reason, and indeed in spite of reason, to a system of an austere morality. The final end of the systems was the same; the means used in arriving at it were suitable to the conditions of the times. This holds not only for general systems of ideas but for particular theories, but before following this in detail it is worth considering the effective function of scientific theories in general.

A scientific theory has a dual aspect: inside science its function is to organise existing knowledge and point the way to the acquisition of new knowledge; outside science it is a form of statement about the nature of the universe. Now it is the confusion of these two aspects that has done so much harm to the position of science in general culture. It is obviously impossible without scientific training to appreciate the positive content of a science because of its extent and intricacy. In so far as it is known to the lay public it must be known by means of its theories, and these theories are almost inevitably taken as presumably true statements. From the point of view of the advancement of science it is not in the least necessary that a theory should be true, or, in the strict sense, that it should even have any explicit meaning. (If we say that the states of an atom are waves in configuration space or probability matrices, we are not making contradictory statements, and in fact are saying little more than that people may express their feelings in French or German according to which they find more convenient.) Scientific theories are usually taken as true by scientists for emotional reasons in order that they may feel a comfortable exhilaration at their work, but for the working scientist a particular theory is merely a popular champion to be abandoned and ridiculed the moment a new and more effective theory beats it in the field. Where titles change hands rapidly, as in recent physics, the lay public begins to acquire a tendency to scepticism, wholesome if only applied to the theories, but apt to spread to the whole method and content of science. On the whole, however, scientific theories tend to turn into lay dogmas believed to be true on authority without the possibility of examination, and it is for this reason that it is the more necessary to examine into their origin.

The scientific worker is apt to overlook the history of science or at least to consider it irrelevant to his immediate occupation,

and in this he seems justified both by the restrictive effect which tradition has had in the past and by his desire not to introduce elements foreign to his actual observations. But from the lay point of view the history of science, particularly of scientific theory, must have a much greater importance because it is the only way by which the validity of scientific theories propounded as dogma can be criticised from the outside. It may even be, in spite of what has been said above, that the scientific worker would gain from such criticism because lack of the knowledge of a tradition does not prevent that tradition from unconsciously affecting all his work.

Now of the two chief elements which affect the history of science from the outside, the possibilities and the needs of the current state of material culture and the current philosophical and religious tendencies, only the second concerns us here, because the first—though more important—leads directly to the detailed content of science and only indirectly to scientific theories. Such books as Burtt's *Metaphysical Bases of Modern Science* bring out very clearly how much scientific theory depends on views of the universe whose bases derive essentially from inner mental experiences and are correlated with moral and religious attitudes. These are in turn determined by social and political evolution.

It has often been noticed how modern scientific theories appear foreshadowed in earlier societies; for example, the idea of evolution, implicit in the almost universal totemism in primitive society; or more clearly in the first formulation of the atomic theory by the Greeks. It is usually said that these foreshadowings are examples of the intelligence or intuition of the people first putting them forward, but as it is admitted at the same time that either there was no adequate evidence for the theory at the time or that its basis was one of false analogy, it would seem that it should lead to the opposite conclusion—not that the primitives showed exceptional insight in arriving at the theories, but that we may be showing notable stupidity in still believing them. Their origins should be a ground of suspicion of their modern forms. The case for this paradoxical statement becomes still stronger when we consider that the connection between the ancient and modern theories is not accidental, but that a historical continuity links the theory as held in the ancient world with the modern one; and even, in a

great number of cases, it is the ancient theory that has led to the propounding of the modern one rather than any evidence drawn from observation. As a concrete example we may take the case of the atomic theory: its origin is obscure, but there are hints of it both in Babylonian and Indian philosophies. Even if we give the credit of its first statement to Democritus we cannot imagine that it was arrived at otherwise than by that analogical type of reasoning that gave rise to the four elements and the four humours. There is no logical support for atomism, no reason, possibly within the reach of the Greeks, to put a stop arbitrarily to the concept of repeatedly dividing bodies; but once the analogy of a universe built out of sand or bricks is grasped, it associates itself with an aesthetic and moral attraction for certain types of mind. A universe of particles—how fascinating to build for oneself such a universe. The particles being inert, the gods retire into an indefinite background, and man is left the master of the universe if he can understand how this building takes place. Atomism emerges into our knowledge in full association with Epicureanism and has been known to the latter ages almost entirely through Lucretius. The Epicureans died gracefully as the empire decayed, but Lucretius' words were still left, and from the eighth to the fourteenth centuries influenced Arabic and Jewish science, while the name Epicurean remained as a term of reproach in both religions. In the Renaissance the new atomists, such as Campanella and Bruno, were more violent rebels against the logomachy of the schoolmen than they were scientists. Descartes was a scientist and an atomist, but one only has to consider his system of vortices to see how little his atomism was scientific and how much it contributed to give him a satisfying aesthetic picture of the universe. Newton was the first, perhaps, to accept atomism from the ancients for other than its ethical or aesthetic attractions. Its usual implications were in direct contradiction to his fundamental religious attitude, but particles did so perfectly fit with his new methods of mathematical analysis that he was almost, *malgré lui*, obliged to be the father of modern physical atomism. The eighteenth century used atoms without necessarily believing in their actuality: they could treat them as infinitesimal or as fictitious bodies. True atomism came in with Dalton, and here we have a clear case of theory preceding observation. Dalton, following Newton

and fascinated by the Democritean picture, was convinced that it must show itself in the laws of chemical combination to such an extent that in his first attempts at verification he made up for the defects of his analyses by a most convenient unconscious arithmetical error. All through the nineteenth century chemical atomism fought a winning battle with the older theories of continuous substance, though Newton's corpuscular light was abandoned in favour of the wave theory. At the end of the century physics again came to the aid of atomism, and when individual atoms could be seen, tracked and ultimately heard, their existence seemed as indubitable a fact of experience as the existence of human beings. The last years have brought strange revolutions: the reality of atoms has apparently disappeared, to be replaced by an equally convenient fictitious atomism, useful for certain calculations as is the concept of fictitious uniform substance for others.

Looking back one can see two dominating desires in the evolution of the theory: first a legitimate scientific desire to have entities amenable to known methods of calculation. If, as is now possible, the calculations can be carried on without the atoms, the atomic theory temporarily disappears until it is found to be needed again. The second and more fundamental desire, as legitimate but certainly not as scientific, is the desire to visualise the building-blocks of the universe and to explain it in terms of the position and movements of these units. For that purpose atomism will probably remain for a long time yet in science. This example shows how a theory, like a language, has both elements of historic continuity and successive adaptations to current conditions.

There is nothing, however, in this view to imply that science has neither truth nor originality; but these lie not in the theories themselves but in how or what they are applied to, just as a language is ultimately judged by the beauty and effectiveness of the literature produced in it. The real cultural value of science lies in the accumulation of realised relationships and in their organisation into a scheme which makes them intelligible. In this, theory plays two parts: active theories, usually provisional and analogical, possibly even in conflict with accepted principles of science, lead to the discovery of new relationships; passive theories, inclusive and systematic, enable previous relationships to be summarised so

that they can be grasped as a whole, and this with the incoming of new relationships means that these theories must also be continually changing. Ultimately, theories are only auxiliary methods of advancing and maintaining science; they are not science itself, and could be and perhaps may be allowed to disappear and become implicit in the scheme of relationships.

The effect of modern science on the public at large has, however, been mainly through its theories being introduced uncritically as if they were statements of fact, and then accepted or rejected according to whether their supposed implications were pleasant or unpleasant to the people concerned. Compare, for instance, the reception of the theory of relativity and of the gene theory of inheritance. The first was received with extraordinary readiness by nearly all metaphysically minded persons, though the real content of both the special and the general theory of relativity was naturally neglected, in the first place because it consisted of difficult mathematical expressions without emotional value. The idea of the theory of relativity as a destruction of absolutes was, on the other hand, successful because it formed a bridge between the tendencies of science and philosophico-religious speculation. The religious-minded thinker, finding that an absolute religious dogmatism was impossible to maintain in face of science and that it was equally impossible for him to accept a dogmatic science, seized on such ideas as the dependence of the truth on the observer's point of view and the formal subjective explanation of the "force" of gravitation as ways of reconciling himself without inconsistency to both worlds. The scientists, on the other hand, were able to see that it was not necessary to attach themselves to a rigid framework of matter and ether in order to explain the data of observation, and that in fact it was better to abandon it, and that made them more inclined to include in their personal beliefs metaphysical elements which before they would have been ashamed to admit. On the other hand, the gene theory of inheritance is one which, had it been propounded fifty years ago, would, on account of its atomistic determinism, have been received with terrific enthusiasm by materialists and atheists and with as much obloquy from orthodoxy as evolution itself. Coming at the present time, however, it arouses scant popular interest because it cuts inconveniently across the harmonising tendencies of the age; so much so that, in spite of the mass of

experimental facts behind it, it is even combated inside the world of biological science, in favour of mystical entelechies, holisms or emergents.

There are three chief ways in which science is presented to the public. The first way is simple popularisation, mostly concerned with the content of science—discoveries and their applications. This suffers from journalistic desire for sensation which tends to cheapen science in the minds of thinking laymen, while it gives rise to unreasoning dogmatism in the uncritical. The second method is indirect and consists of references to scientific theories in works of a non-scientific character, particularly in modern philosophic, religious and psychological literature. The writers of these books are not scientists: they obtain their information on science in general from popular works, and if the science they contain is inaccurate or tendentiously twisted the fault lies with the scientists who have failed either to provide them with accurate information or to correct them in their mistakes by a vigorous polemic. The third—and from the standpoint of this article the most important—class of popularisers are those eminent scientists who from time to time write about their own science in relation to wider problems, philosophical, political or religious, etc., of the time. They are important because they are taken, rightly or wrongly, to be speaking for science, which for the greater proportion of people must be taken on authority—and they are the holders of that authority. It is by considering their writings that we can see how the state of harmony between science and other methods of thought has arisen. The chief fact, as seen above, is the confusions between the content of science and scientific theories, but that explains only the mechanism and not the operating factors. These are various and difficult to trace, but there are two or three that cannot be overlooked. More particularly one of the most notable factors is the preponderance of physicists and mathematicians among those who speak for general science. This is a very old tradition, temporarily suspended in the nineteenth century by the appearance of a few vigorous biological thinkers. Now the theoretical physicists, from their primary concern with mathematical formulae, are apt to pass over very easily into metaphysics, and once that boundary is passed it is very difficult to put a stop to loose thinking. The mathematician is not critical

of the actuality of things: the most absurd statements can be readily accepted as long as they make a formal logical whole. Nature itself is for the physicist simply a set of observations to be reduced to mathematical formulae—to reduce the most extravagant theologies to other formulae gives them equal satisfaction—witness the great Hindu mathematicians and even Newton, one of the most concrete-minded of great physicists. This lack of a sense of reality, coupled almost invariably with an absence of psychological criticism, leads to an almost mystical subjectivism once the boundaries of strict science are crossed. The trouble is that as time goes on these boundaries become more difficult to define, and the reader is either carried by the author's authority in the belief that his metaphysics are science, or is so struck by ultimate vagueness that in face of it he finds himself justified in keeping to his own beliefs on the basis of the convenient principle "why not?"

Modern physics is supposed to have destroyed the older materialism and this is supposed to be an excuse for holding any kind of opinion, mystical, philosophical or religious. In fact materialism has grown so rapidly that it has temporarily lost its language and is rapidly in the process of finding a new one through the connecting of the biophysics of sensation with the ultimate wave-mechanics picture of the universe. But supposing materialism had lost its justification, there is still no excuse for returning to beliefs which will not tolerate historical or psychological criticism. If science is misunderstood at the present time, it is mostly for the lack of this criticism. The effect of biological writers in countering this is less than it should be because of the wide divergence in biological thinking contrasted with the unanimity of chemistry and physics. The difference between them is that while in physics it is the meaning of the ultimate ascertained facts that is difficult to grasp, in biology it is the unknown portions of the subject—the territories of life, organism, etc.—that leave loopholes for emotional thinking. There is nothing new about vitalism in the sense that the quantum mechanics is new, and as long as there is any part of the organic field yet unexplored there will always be vitalists to say that its phenomena cannot be explained. This does not prevent experimental biologists from unravelling one of these mysteries after another, but the vitalists get the better publicity, because to hear an eminent scientist saying that such and such

a problem can never be solved is encouraging to those who are never likely to solve any problems themselves. As to psychology, it is not specialised enough for its methods and conclusions to be out of the reach of the intelligent layman, and although it is safer to speak of psychologists rather than psychology, we must turn to it ultimately to deal with the difficulties of the appreciation of the results of physical and biological science. That is really the task of the future. It is not that psychology will be required to alter or add to the content of our knowledge of the physical, biological universe, but that it will clear up the confusions and misunderstandings that the interpretation of that knowledge gives rise to, and will separate from them that mass of ancient mysticism and magic which has nourished science in the past, but which, if allowed to continue, would soon stifle it, as the experience of the Greeks has only too plainly shown. This is admittedly a hope rather than an actuality.

What are the possible attitudes in the present? If, as I have tried to show, science can only be grasped as a whole through scientific theories and these theories are merely uncertain hypotheses, not even arbitrary but deriving from venerable tradition of dubious origin, is there anything left on which to found rational beliefs? There may not be any such basis of certainty, but the alternatives are not a general scepticism or an eclectic faith. If there is no passive background of belief, there is its active equivalent, the method of science itself: the continuous discovery and refining of discoveries, the acceptance of organising hypotheses as merely convenient and provisional, and the experimental critical attitude towards every dogmatic proposition or system of belief. To those who have experienced it, this fluid, uncertain attitude has its own satisfactions as real as those of any dogmatism, and once held can never be abandoned, because it is part of living itself.

1929

THE UNHOLY ALLIANCE

FIFTY years ago we used to hear a lot about the warfare between science and religion; nowadays it is all different. Eminent scientists like Jeans and Eddington claim that this warfare was all a mistake, that real science and religion mean exactly the same thing, and their offers of peace are willingly welcomed by progressive bishops. What does this mean? Does it represent any real reconciliation between science and religion? For the answer to that you must look in the laboratories and in the world of politics. If you ask a working scientist whether he finds the idea of God of help to him in his researches he will only look puzzled. There has never been a time when science has been more able to deal with its own facts without any imported assumptions. Outside the laboratories it is a very different story. Science is too dangerous nowadays to be popularised without being sterilised by making it fit in with religion. In practice this is done quite simply. A scientific book or broadcast address which backs up religion becomes at once a best-seller and is well-paid. If it goes against it it may be published in a small way by a rationalist society but will certainly never get on the ether. And the reason is that if people knew what science could do for humanity nowadays and what they are being defrauded of in the way of security, comfort and leisure by the inability of the present system to apply science, that system would not be allowed to last much longer. If science were used properly there would be no need for anyone in the world to go hungry. Even without tilling an extra acre of ground there would be enough food for at least twice the present population in the world, and by using all the good land available there would be enough for something like two hundred times; and if that wasn't enough we now know how to make the basis of food out of water and air. In a properly organised world, even without any new inventions no one need work more than four hours a day, while it is hardly necessary to say that if we could get rid of economic and national rivalries, the danger of war, which is a terrible threat hanging over everyone's life, could be removed and the whole of the scientific ingenuity now used for armaments could be turned to constructive purposes.

But all this is science, not religion. Religion is there not to change the world but to keep it as it is for the benefit of those who get the best out of it. This has been so ever since wealth and private property appeared in the world. There was a time of relatively harmless, natural religion where everything that man could not understand or explain was put down to local gods and spirits, gods of thunder, gods of rivers, gods of the garden and of the fireplace. This was good enough when people lived simply off the soil, but when nobles, kings and emperors arose to take all the surplus and some of the necessaries of life from the peasants, order was brought into this system. There was one big god and a lot of smaller ones; he gave the orders, they did the work. This is the system that we find not only in Greece and Rome, but in early Christianity. The picture of the world in the Middle Ages was very easy to understand. God was in the sky, around him were the angels. The higher ranks were entirely occupied in singing his praises, the lower orders were running the world. The earth was the centre; around it were the spheres of the sun, the moon and the planets, each kept turning by its appropriate angel. The minor angels were devoted to affairs on earth, but for most purposes the saints were better because they had been there. On earth each man kept his proper station, obeying in worldly matters the nobles, kings and emperors; in spiritual matters the priests, bishops and the pope. Below the earth was hell, occupied by the angelic opposition. Everything kept its place as in a well-ordered state except on special occasions when God would send a comet down to warn rulers that the Church must not be flouted, or the infernal forces would break out in an earthquake or volcano.

This very complete reconciliation of science and religion was broken up four hundred years ago by the increasing importance of merchants and bankers and their use of the power of money to change the old forms of life. With them appeared a new science which shattered the old ordered scheme to bits. The earth was no longer the centre of the world, heaven was not just a roof a few miles off, but instead infinite space stretched from star to star. The actual substance of things became a blur of dancing atoms. All this was at first very disturbing to religion and it was intended to be so. The merchant class had to fight their way against the old nobility of the Church: they set up

the Reformation, they broke the nobles in the civil war. After a while, however, they found they needed a reconciliation between religion and science just as the Church and nobles before them, in order to keep down the propertyless workers that their own trading operations had robbed; and so there was a new reconciliation which is usually known as the work of Newton, though it was not so much his alone as that of a whole group of brilliant scientists of the seventeenth century. In this system God has retired from the immediate supervision of the world and his place is taken by scientific law. Instead of angels pushing round spheres in the heavens the separate planets move in their orbits by the law of gravitation and God is only needed at the beginning to give them the first push. God remains behind events, looking on as a benevolent providence, but he does not interfere. The moral is no longer that everybody must keep to his place in the universe, but God helps those who help themselves. Even man was no longer a little world in himself, with heart, liver and lungs to correspond with the planets, but a mere machine supplied with an immortal soul to pull the levers.

For a while, just before the French Revolution, thinkers dared to go even further and leave God and the immortal soul out of it, but the Revolution was a serious shock. Rising workers made freethinking bankers and bishops see that there was a lot to be said for religion, and back it came in full force all through the first half of the nineteenth century. Meanwhile the scientists were quietly working away clearing up one after another the mysterious things that had made people call on God for an explanation. Living matter was shown to be no different from non-living, and finally Darwin showed that man himself was an animal descended from animals.

It is important to remember that Darwin did not prove the doctrine of evolution; that proof is only now being completed. Nor directly did he discover it: it had been foreseen fairly accurately years, even hundreds of years, before his time. What he did was to make it an understandable and attractive doctrine to the ruling class of the time. The explanation of evolution which Darwin offered was that new forms had arisen and old forms had been wiped out as the result of free competition in the struggle for existence between slightly varied forms. This was called Natural Selection, and by implication

it meant that the way to get on in the world of free-trade capitalism was not only a practical way but was the way of nature itself. Darwinism is simply Victorian liberalism in natural history. When it came out it was rather too much for the Church of the time, which still had its roots in the past and belonged to the Tory party and the old land-owning aristocracy. They fought it fiercely for a while; if everything new and successful came by evolution, what justification could be given for institutions established from the beginning by God? But it was not very long—thirty years at the most—before the struggle took on a more gentlemanly aspect. The Churchmen found that the scientists were not so dangerous after all. It is true they could not be got rid of altogether, and the monopoly of the Church of making statements about the world at large was broken for good; at the same time they were not unreasonable, they were willing to share the field with the Church. Thomas Henry Huxley provided the solution. He called it Agnosticism: science, even nineteenth-century science, did not require God, it could get on quite well without him, but it did not *know* that God did not exist. Science could prove that the material facts which were the basis of religion, the creation, the story of Adam and Eve, the deluge and the whole crop of miracles were all plain lies, but it could not prove, and it felt it had no right to suggest, that they might not contain some deeper spiritual meaning. And so there was a basis for a compromise: if science sticks to the world of facts and religion to the world of moral and spiritual matters, no real conflict need occur.

But a compromise patched up with such intellectual dishonesty could not really last. Neither side played fair. The scientists, whether they wanted to or not, were bound to go into the world of spiritual matters and moral values. Those very *experiences* which were the basis of personal religion would turn out to have a remarkable likeness to certain symptoms of milder kinds of lunacy. The rites and sacraments of the churches kept on turning out to be extraordinarily similar to those of the ancient East or of modern savages. Of course there must be something different and superior about them, but it became increasingly difficult to find what that something was. And the churches on their side had not been idle; the very bases of science itself began to take on a theological

air. The nature of sensation was in question and a new brand of positivist critical science grew up which denied the existence of an outside world at all, and maintained that all we could be certain of was sensation. In what way, therefore, was scientific certainty any better than religious certainty? This was the state of affairs at the end of the last century, the intellectual atmosphere in which most of the present-day scientists were brought up. On the one hand they had a very definite set of theories and laws which made up the body of science, and on the other the whole range of moral and emotional, artistic and religious experiences which had nothing to do with science, and which by their colour and variety lent some relief to the rigidity and deadness of the scientific dogmas.

Suddenly, just about the turn of the century, the most remarkable things began to happen in science. Established scientific theories appeared to be completely overthrown as the result of new discoveries: in physical science, X-rays, radium, the electron, the structure of the atom, the nature of chemical attraction; in biological science the discovery of the chromosomes and the genes and the new biochemistry of hormones and vitamins. These discoveries were not accidental, they were due to the accumulation of technique of the nineteenth century and the greater endowment which was now flowing into science not only from governments but from the growing capitalist trusts. Sooner or later there was bound to be a break in the older conceptions, and once that break occurred new discoveries were bound to follow thick and fast. What with the new discoveries and the war the scientists were too busy for the first twenty years of the century to bother about their philosophical bases or their relations with religion. It is true that Lenin found time to draw up a damning indictment of religious and scientific hypocrisy in *Materialism and Empirio-Criticism*, but that did not get across to the scientists in Western Europe until many years later. The temporary stabilisation of capitalism between 1921 and 1929 was an opportunity for reviewing the relations of science and religion in the light of the new discoveries, and of the recent political events. The need for a reconciliation between science and religion was greater than ever, because for the first time in history there existed not only a body of men but a powerful and growing state in which religion had been openly proclaimed unnecessary and harmful,

while science was to be the basis of the reconstruction of material and social life. The fear and the portent of the Russian Revolution overshadows all popular scientific writing of the time. It was not difficult to find opportunities for a new reconciliation in the recent advances of science. The first great opportunity was Einstein's relativity theory which has given rise to as much popular nonsense as it has to intricate mathematics. Because, owing to the presence of matter, we cannot see quite straight, or as scientists prefer to put it, space is curved, philosophers argue that nobody really knows anything about anything, and that it all depends on your point of view. Even the much more important quantum theory, which has given us an immensely extended understanding and control over chemical and electrical processes, is made in the hands of Jeans an opportunity for similar mysticism. The changes in the appearances of the properties of things that we call chemistry are the results of movements which occur on a scale altogether too small for our senses to appreciate them directly. To handle them conveniently we have recourse to certain arguments which for convenience are put into mathematical symbols. The things with which these symbols deal are not the ordinary objects of our senses, though those objects are made out of them. But, argues Jeans, if we cannot say what the things are, they cannot be ordinary things; they must be purely mathematical themselves, and since the universe is made out of them and God made the universe, God himself must be a mathematician. The argument is not a new one. Plato put it forward in ancient Greece, and it is probably three thousand years older than that. But when it was first put forward it was an honest attempt of the people who had just evolved the basic trades—the smiths, the carpenters, the potters—to explain the making of the world in terms of the things they themselves were making for the first time. Now it is the last apologetic attempt to preserve a tottering social order. It is honest only in so far as those scientists who still put forward their mystical views are debarred by their own choice from seeking the explanation of their difficulties in terms of a real science of sciences, which is part of dialectical materialism.

1930

THE EFFECT OF SOCIAL FORMS ON SOCIAL SCIENCE

THERE has always been an interaction between the forms of society and scientific knowledge and achievement in the widest sense. On the one hand, the development of knowledge has made certain social changes possible, and on the other, social development has made demands on knowledge that have in turn advanced its boundaries. The idea that the problems of human society, both economic and cultural, must be dealt with in a scientific way is one which has taken long to develop. It is true there has been a close connection between science and society from the moment science itself became a conscious activity, but the nature of that connection has, in the course of time, undergone many transformations. Only lately, outside a few minds, are its full implications beginning to be glimpsed. Before anything effective could be done about it it was first necessary for human society to be conscious of itself and of its place in the development of the universe in a scientific way. This is a relatively recent achievement. But it was also necessary that science should, in response to social needs, furnish the mechanism for acquiring material control over nature. With this, the understanding of society could become the means of enabling it to reach its full development.

The earliest, and in a way the most important, period of this interaction is tantalisingly hidden from us in the obscurity of prehistory. We still know practically nothing of the origin of civilisation, meaning by that the complex of agricultural and technical achievements implicit in village and city life. We do not know how the arts of pottery, metal-working and weaving, which remained substantially unchanged from 5000 B.C. to A.D. 1700, arose in the first place. But we may suspect the existence of a period of perhaps a hundred years or a millennium, corresponding in intellectual and practical activity to the industrial revolution of the eighteenth and nineteenth centuries. At first the new discoveries must have been seen as agents of human liberation and esteemed as such. The deification of the early cultural heroes—of the Daedali and Imhoteps—points to some vague memory of their former importance.

Then, once established, progress apparently stopped for about 6,000 years, though in that time civilisation, cradled in Persia and India, spread all over the world. The social custom of war, arising as a by-product of commerce and exploitation, may well have been the cause of both the stagnation and the spread of culture. Certainly during all these centuries war was a dominating social force and the arts and sciences were taken for granted and correspondingly despised.

How completely this had occurred can be seen if we consider that brief respite in the cycle of conquests and migrations which we call the Greek miracle. In Plato's *Republic* we find, it is true, a very conscious attempt at defining the proper functions of society, one which is a logical starting-point of all further attempts at rational sociology. But what a reactionary picture it paints! The completely static state is modelled on Sparta, the most primitive of all Greek communities. A certain value is placed on knowledge of words and forms but none on crafts. There is no idea of betterment because, realistically enough, Plato sees that increased wealth, monopolised by the rich, leads to civil strife and military weakness. But above all there is insistence on defence and military training as the main object of the state. After Plato came more weary wars, and although in the Empire the Romans managed to achieve impressive results, by large-scale organisation rather than by improved technique, the essential static and even degenerative picture of society remained. The best thing people could hope for, as the success of the messianic religions showed, was the complete destruction of the world.

When the old world had broken down, as much from its own inefficiency and hopelessness as from external attacks, and man still lived, a new spirit began to appear. People knew vaguely that the ancients had done great things, that much had been achieved through knowledge and reason. The recovery of these in the West marked the beginning of a process in which we are still involved. Abelard with his insistence on reason and Roger Bacon who first pointed to the practical value of knowledge are the vocal heralds of a process which was quietly developing in the workshops of mediaeval craftsmen and builders. It is true that the Middle Ages did produce as static a concept of society as any previous time but in practice there was no standing still. Trade and money effectively broke up

the primitive feudal economy and led to a state of affairs where knowledge and ingenuity were at a premium. Even the return to the ancients expressed in the Renaissance could not stop the movement.

The birth of modern science in the sixteenth and seventeenth centuries coincided by no means accidentally with great developments in commerce and manufacture. The preoccupations of the men of learning changed abruptly from theological to utilitarian ends. The needs of navigation inspired the work of astronomers; those of warfare and manufacture, the mechanics and chemists. In Francis Bacon we have the first full expression of the idea of science as a means for increasing wealth and the general improvement of mankind. In the foundation of the Royal Society forty years later the task had been definitely taken in hand. As Robert Hooke says in the preface to the *Micrographia*:

> And the ends of all these Inquiries they intend to be the Pleasure of Contemplative minds, but above all, the ease and dispatch of the labours of men's hands. They do indeed neglect no opportunity to bring all the rare things of Remote Countries within the compass of their knowledge and practice. But they still acknowledge their most useful Informations to arise from common things, and from diversifying their most ordinary operations upon them. They do not wholly reject Experiments of meer light and theory; but they principally aim at such, whose Applications will improve and facilitate the present way of Manual Arts.

This conception of the relation of science and society was, of course, extremely limited. It was based on the comforting idea that what increased the private wealth of the projector and his friends would necessarily benefit the whole of the human race. It has taken some three hundred years to show the falsity inherent in ignoring the social by-products of practical scientific advance. This is less surprising in that the general conception of the early scientists was excessively mechanical. Newton and his rigid laws seemed to give a model on which the whole universe, social as well as astronomical, revolved.

But already in Newton's time other ideas were beginning to appear. In the obscurity of Naples, Vico struggled vainly against the predominating mechanical temper of the age. Clinging to the classics and scholastic theology, he managed to

see something that the scientists, in their haste to achieve practical results, had overlooked. "The physical world was made by God," he declared; "it is not for man to understand it, but the human world, the world of society and history, was made by man and can be understood by man." With extraordinary insight, when one considers his ignorance and his prejudices, he saw the institutions of human society in organic and regular development. *He saw that what people thought and how they spoke depended on the form of society* in which they lived and how those forms in turn broke up and changed themselves into new forms.

Vico lay outside of the general stream of thought. In the seventeenth century the utility of science was a pious hope, in the eighteenth and nineteenth it had become an actuality. The men of the Enlightenment—the Philosophes, and the English scientists—considered that the destruction of superstition, the promotion of useful knowledge and the provision of institutes for the arts and manufactures were the chief contributions that science could make to society. Given sufficient knowledge and the absence of governmental restrictions, self-interest would provide the best satisfaction of human needs. It is characteristic of the early application of science that needs were taken for granted. Man retained the habits and desires of previous ages, but he had found mechanical means of satisfying them.

By the beginning of the nineteenth century it was no longer possible to doubt that although science had improved the convenience of life for the wealthy and made it far easier to become wealthy, yet at the same time the poor did not decrease or become any less miserable. It was impossible to reconcile this with the idea that science was a universal benefactor, while nevertheless its real gifts were undeniable.

It was all the more necessary therefore to justify the attendant evils, since it was clearly nobody's business to remove them. This was the work of the economists and the moralists who first proved that poverty was inevitable and then that it was a crime. The economists contributed little directly to the scientific conception of society because to them society hardly existed; it was merely a number of individuals engaged in commercial transactions with one another.

Indirectly however they did contribute by the controversies

they stimulated. Malthus, in particular, by showing that poverty and disease were necessary to prevent the population from overrunning the means of subsistence, suggested to Darwin that the same process must occur in the animal world. But here it was not just a mechanism to preserve an existing state of affairs but the stimulus which changed the forms of living things by natural selection, it was the motive power of the evolutionary process. At the same time Marx and Engels had seen that human affairs represented not a static state, subject to immutable laws, but a dynamic development incomparably faster in its rate of transformation than was organic evolution. The very phenomena of poverty which Malthus had described appeared to them as a product of the phase of machine industry, and in turn the motive power which would transform a social framework fitted to an earlier stage of economic and technical development into one where the new means of control over human environment could be used to the full.

In more orthodox circles these views made their appearance far more slowly, but yet, as the century wore on, there began to appear under the stimulus of the theory of evolution the idea of the study of society for its own sake. Spencer and Galton took up sociology, a term coined by Comte. This was, however, a very pure study, aiming at description, preferably exact description, rather than experimentation. The great advance that was made came as a result of the increased knowledge of barbaric and savage races and the unravelling through archaeological excavation of the history of past civilisations. By the end of the century the picture of the development of man from the palaeolithic hunter upwards began to be visible in its broad outlines. The enterprise of human society and its struggle against both natural forces and the difficulties of its own making could be appreciated as a whole.

Meanwhile events were moving much more quickly than the apprehension of them. Free competition had turned into that government-aided monopoly we call imperialism and imperialism had brought war. It was only after the war, in the first burst of enthusiasm for reconstruction, that the idea of a planned world society to satisfy human economic and social needs appeared for a moment outside the minds of dreamers and communists. The picture soon faded. The Russian Revolution had occurred but had been so libelled that only a few

faithful imagined anything would come of it. Even the brief prosperity of the twenties could not hide from people that a rational organisation of society had not been achieved.

The coming of the great slump brought a sharper realisation. The rational society had appeared before as a desirable ideal, it now appeared as the only safeguard against catastrophic economic deterioration and complete destruction in modern war. At the same time, the progress of the Soviet Union was demonstrating that the evils of the times were not inevitable natural phenomena, but could be avoided with a different social organisation. The five-year plan was beginning to show its possibilities. Inspired by these events there arose, particularly in England and America, numerous societies of planners, currency schemers, technocrats, etc. All had in common that they saw that the immense possibilities of human production —not now, as in the nineteenth century, only of manufactured goods, but of all human necessities—were not being used on account of faulty economic and social organisation.

These movements had two new features. In the first place their analysis always attempted to be quantitative, to measure exactly what basic human needs were and what needed to be done to satisfy them; in the second place, they were practical and tendentious. They were beginning to think in terms not only of a pure, but of an applied sociology. Human affairs were at last coming into the sphere of science not only passively but actively, and an economics which simply concerned itself with profit and loss was despised in favour of one which discussed the problem of human needs and technical means to satisfy them.

This is our present situation. The problem has been set, but it is idle to think that in this country we have even started solving it. Even now, the question is confused by much false analogy, prejudice and interest. We have not yet, for the most part, achieved an attitude towards human society sufficiently objective and at the same time realistic and active. Happily some of the new experiments in social organisation do show a disposition to do so—especially the U.S.S.R. And it is precisely here that we see the most extensive subsidising of science.

Society is difficult to understand, partly, it is true, because we are in it and not outside it, but also partly because in human society we are considering not a stage but a process. In some

ways this process is like the process of evolution—the self-development of new forms—but it is an incomparably more rapid process and in our time is moving faster than human life. Men can adapt imperceptibly to social changes which take centuries, but those that take a few years provoke the most violent conflicts and dislocations. Science as we know it has not developed a technique for dealing with things which change of themselves largely because such changes are usually too slow to bother about. *If we are to apply science consciously to human society, we shall need to change science* and change it in a way as fundamental as that in which science changes society. We shall have to learn the active and not only the passive voice of nature.

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TRANSFORMATION IN SCIENCE

ONE of the paradoxes of the present time is that people may be able to change the world so rapidly that they fail to understand what they are doing. Another is that, while more has been found out at large and in detail about nature and man in the past thirty years than in the whole of history, there is less general appreciation of this knowledge and worse use of it than ever before. This is partly because modern science has become more complex, but as much because it has been professionalised. Since some people are paid to understand it, why should the rest bother their heads about it? But ignorance of science means a failure to understand the factors underlying the critical events of our time. The history of the last few years should have shown that it is no longer optional, but absolutely necessary, for science to be understood, appreciated and effectively used.

The war is simply an acute phase of a process that has been going on with increasing violence for many years. The whole of human society is passing through an enormously important transformation. The material bases of this transformation are the changes in production which are inseparably linked with science. It is taking place far more rapidly than any of the

transformations that occurred in the past; so much so that individuals seeing overwhelming changes in their own lifetime are utterly bewildered and are carried along, without ever understanding the underlying factors. The old men, who in most parts of the world still nominally direct affairs, have by tradition and education no knowledge of the tremendous forces that are shaking the world today. They know little or nothing of modern science or economics, and are powerless either to keep out of dangers or to extricate their countries from them. Their younger successors in the fascist countries are equally ignorant of the facts of science, but appreciate far better its practical possibilities, and know well how to use it for destructive ends.

The tragedy of the present struggle is that the ends for which people are striving—food, work, security and freedom—are gifts which science has put within reach of all. The resources, the knowledge and the ability to build a new world are there, but instead we have danger and bloodshed, want and misery. If people could understand at least something of the possibilities which science offers, they would become more reasonably impatient of their present state, and more capable of changing it. For this, science needs to be expounded, and expounded in a new way which emphasises its relation to a changing world. It is no use any longer attempting to present science as a series of pictures of the beauties or the mysteries of the universe and of nature. People have had enough of that already; it belongs to a time when individual and social security and the general running of society could be taken for granted. Indeed, the public is very justifiably irritated with the idea of the pure scientists' leisurely and secluded search after minute and remote things, when the world all around is being bombed to pieces; especially as the aeroplanes, guns, tanks and other engines of destruction seem to be the most noticeable products of scientific research.

But in any case the scientists themselves are no longer anxious to present a merely academic picture of a disinterested search after truth combined with a sublime indifference to the results of discoveries. Science has long been much more than this. It has become an integral part of productive industry and agriculture, it maintains health, it is increasingly involved in business administration and government. The methods and

ideas of science are the dominant forms of thought and action in our time.

The difficulty of getting hold of modern science is that it is moving so fast. In the past fifty years, and even more in the last twenty, it has achieved an internal revolution. Mr. Herbert Read[1] is quite right in tracing the parallel between the revolutionary movements in art and science, but in my view he takes in too broad a sweep. Although twentieth-century science rests securely on bases laid down in the nineteenth century, the twentieth century has a character all its own; and the revolution in science is, in fact, far more significant than that which occurred at the end of the eighteenth century.

Four Transformations

Four great internal changes in science occurred just before the beginning of the century: the quantum theory, which has led to the understanding of the structures and actions of atoms and molecules, and thus to the complete union between physics and chemistry; the rise of biochemistry, which has revealed the extraordinarily complex but understandable chemical basis of living organisms, and shown that this is far more significant than the grosser forms and movements that occupied the naturalists of the nineteenth century; the discovery of the material basis of inheritance in the chromosomes; and finally, that ill-defined but vitally important advance in the study of animal and human behaviour which is beginning to break down the last stronghold of metaphysics—the conception of an independent category of mind.

Now these great advances, actually incomparably richer than those in the whole previous history of science, are also essentially different in character. In recognising them, the scientists have been forced to adopt new mental attitudes which involve a break with the traditions of thought reaching as far back as the Greeks, if not further. The simple logic of the schools derived from grammar and common sense has been found inadequate to cope with the more remote complexities of the atom and the starry universe. Relativity and the quantum theory both involve what seems to the common man

[1] "This Changing World" Series 2, chapter i, "Threshold of a New Age," Geo. Routledge, 1944.

absurdities and contradictions; but these contradictions are now established as necessary parts of the behaviour of our universe.

We see now that what we call common sense is just a convenient but crude human tool, suitable enough for a simple life, but needing to be refined and extended to use the new knowledge effectively in a complex situation. It is in respect of its apparent absurdities and contradictions that modern science shows its relation to modern tendencies in art. By breaking with tradition the new painters and poets have greatly enlarged our sensuous and imaginative experience, and it is no accident that in their imagery and form they draw so much on science.

Organisation

Another crucial advance is that modern science has come up against the behaviour of organised systems, not necessarily always living ones, and is forced to recognise that the very existence of organisation implies properties in the whole which are not separately evident in the parts. Chance events on one level appear as statistical laws on another. The high degree of isolation and independence that marked Newton's science is now giving way to the study of group and co-operative phenomena. The ideas of Marx and Engels, which foreshadowed this development a hundred years ago, are now being studied and appreciated far better than they were in their own time. Further, all parts of science are seen to be much more closely related to each other; and the tendency is to even closer relationship. This implies new problems of organisation in science, and intercommunication between the various branches. The old isolation of the specialist is rapidly breaking down. Team-work is taking the place of individual competitive attack on problems.

Now Science is an Industry

With all of this comes an increasing dependence on the world outside science. In the first place, the very growth of scientific work has turned science from a spare-time occupation of a few dozen gentlemen of leisure into the whole-time job of some hundreds of thousands of research workers in nearly every country in the world. Science has become an industry, a small

but key industry. The cost of scientific research is borne directly or indirectly by industrial contributions, and already there are far more scientists working for industry than in universities or independent institutes. The very progress of science itself would be quite impossible without that of industry. The great discoveries of the present century were made possible by the industrial application of nineteenth-century discoveries. Without the mechanical technique or the ready availability of instruments of the chemical and electrical industries, modern physics and chemistry could not exist.

Through its connection with industry, if for no other reason, modern science is inevitably affected by external political and economic trends. The growth of monopolies has made possible the creation of well-endowed scientific research institutes, but the restrictive policy which followed the economic crisis of 1930 was strongly felt in the scientific world, and gave rise to serious doubts and questionings. The old nineteenth-century optimism of science, the idea that its application automatically led to ever increasing progress, was found no longer tenable. But what was to take its place?

The war has given a terrible urgency to the problem of the proper relation of science to human affairs. It turns out that although science has been used very largely for the development of weapons, it is needed no less urgently for the problem of preserving the life and health of the population under the most difficult circumstances, for providing food and shelter and checking disease. This brings to the foreground the essential function of science, which is in the first place to find the means of satisfying the most elementary human needs. What is seen as a necessity in war was no less a necessity in peace. If the function of science had been fully realised then, the want and misery which led to the war would have been removed without the need for a struggle that can only waste human resources and destroy the powers of human thought.

But it is clearly not sufficient to state this. In fact, it was stated over and over again before the war to little effect. There were reasons, and very weighty reasons, why science could not be used for human betterment before the war. Those reasons still remain, and the way to remove them will only be found when they are understood. So the scientist was forced, and is being forced, to try to understand the conditions moulding

society and determining the resistance to rational schemes of betterment.

Science—Art—Politics—Life

We may find reflected inside the world of science the same general trends as are seen in the arts and in politics. In the first place, there are those who, disliking intensely the present state of affairs, see in it only the culmination of the application of science. The solution to them is to abolish the present and go back to the comparative happiness of an ignorant past. Their appeal is to religion, to the values of the land and the family. These are the views which were put forward with almost conscious hypocrisy by the Nazis, echoed in Vichy France, and even by considerable bodies of opinion in England and America. They imply complete admission of human failure. "Man has acquired certain powers, and has not learned how best to use them. He is inherently stupid and wicked, and had best recognise the fact and not attempt tasks beyond his powers." Such reactionary cries have been uttered at every crisis in the past six thousand years. They recall the protest against the impiety of Prometheus, who took fire from heaven, or the ancient Chinese philosopher who declaimed against the wicked innovations of boats and wheelbarrows. Moreover, it is as difficult to move back as it is dangerous to move forward. We shall certainly have to adopt social habits totally different from those suitable to separate villages of self-sufficing peasants. The fact that modern industry, both for technical and defence reasons, tends to spread itself over the countryside does not lead to increasing simplification but rather to a greater emphasis on efficient organisation and integrated planning.

Outside the simply reactionary camp there are still, however, fundamental differences of opinion, and these are almost sharper in science than in other fields of thought. The tradition of science still carries marks of its social origin. Modern science was created by the same movement that made capitalism. It is strongly attached to ideas of individual initiative and freedom of thought. However, the result of the combination of scientific technique and capitalist economy has been the creation of national and supranational monopolies, in the growth of which the old individualistic methods of industry have largely disappeared. Modern science, with its expensive equipment,

its need for elaborate organisation and its close relation to industry, did not, indeed, even before the war, conform to the liberal idealist picture. Independent scientists had almost disappeared.

National Science

The war has already resulted in bringing science in every country in the world, America included, into the orbit of national defence on the basis of organised planning. Liberal scientists have a very natural fear that this will result in the destruction of the spirit that made science possible, and in the loss of the ideals of free inquiry and free application. Some are even willing to acquiesce in a situation in which science will be quite a minor and ill-rewarded human occupation, provided that it is left alone by the state and industry; but this hope is as certain to be disappointed as that of the more thoroughgoing admirers of the past. Science is too useful, indeed essential, to the day-to-day running of modern industry to be allowed to sink into a safe obscurity. Science can only live when it is in the forefront of human activity. What is needed is a more thorough analysis of those characters in scientific work that make for initiative in discovery and theory, and for critical thoroughness in the establishment of facts. It has already been found in practice that it is possible to retain these characters, combined with quite extensive organisation, as long as the scientists are given responsibility and allowed to arrange their own work. What has been done, and is being done, for war, could be done equally well for peace. The world of science has fortunately always been free from many of the mercenary motives that hinder co-operation in other spheres of life. Democratic collaboration is the essence of the work of a laboratory or the study of a whole range of natural phenomena.

Conscious Planning

One implication is that science can no longer stop short at establishing facts. It must go on to see that its discoveries are adequately and rationally utilised. It was in the Soviet Union that this was first realised. There science has for many years taken a leading and recognised part in planning the utilisation of national resources to the best advantage. The assessment

of human needs has led to the rational study of the best ways of meeting them, and given a broad direction to the progress of scientific research. Many scientists of the old school have feared that this would lead to the destruction of pure science in favour of applied. This has not proved to be the case. Pure science is probably being studied as intensely and over as wide a field in the Soviet Union as in any other country in the world, and certainly more so than in wartime England. In war, indeed, all countries are obliged to push forward with pure and applied science together, and the very critics of planned applied science are often in the forefront of this effort.

In practice, the intellectual and material concerns of the most active leading group in the community dominate the form and content of scientific thought of the time. The seventeenth century was the age of mercantile adventure, and sciences connected with navigation and gunnery held first place. At the end of the eighteenth century the rising manufacturers directed science towards chemistry and the study of heat. In the nineteenth century the lead passed over to electricity. In every case, science served the interests of a limited group, and its benefits to the rest of the community were incidental. The essential difference between the present and the past is that we now have the possibility, and indeed the necessity, of organising consciously what had before merely occurred from the unconscious play of social forces.

To organise consciously the machinery of civilisation naturally puts a much greater responsibility on human beings than they have had in the past. As long as no one is capable of following up the general effects of human actions the most terrible consequences can occur, and no one will be to blame. Indeed, the classical economists have always been able to demonstrate that crises were quite accidental by-products of a fundamentally sound economic system. But once man consciously takes charge of the general organisation of production and distribution, the governing powers can rightly be held responsible for any failure. But we are still far from an ordered economic system, planned for the general good, and a long struggle lies between us and its achievement. Nor can the benefits that an ordered society can bring be achieved all at once. The task is one enormously greater than any man has before attempted. That any solution is possible is due only to

the development of scientific technique and scientific methods. The technical side of human organisation on a world-scale is already there. We know how to make the goods, how to distribute them, and how to ensure the necessary communications. Even more valuable is the knowledge science has brought as to how to study and measure such a vast and complex thing as the changing needs of a human society.

Science Enslaved

The consciousness of the unity of mankind as an effective working community can only be realised by the use of science. The danger inherent in the present situation is that an attempt might be made merely to utilise science in a limited way to serve special ends. This process may at first be extremely effective, as Hitler has shown in the building up of the terrific striking power of the new Germany. To Hitler the scientist is an intellectual fool, who can produce useful results under orders. This attitude is not limited to fascist countries. The effective rulers of all capitalist countries have treated science as a useful and docile slave; and many leading scientists are only too ready to accept this role. But science used in this way can only result in increasing the misery and difficulties through which civilisation is passing.

Knowledge is not something to be harnessed like inanimate power. If it is, the stupidity of the ends outweighs the technical excellence of the means. Already far the greater potential productivity of science goes into war, and war everywhere is the force directing the trend of scientific advance. To reap the full benefits of science, there must and can be an intimate relation between science and social processes at every stage: in assessing needs, in studying and modifying social forms, in production and distribution problems, and finally in keeping guard over the results of its application, to see that they do not turn in unforeseen and undesirable directions.

Scientific Democracy

For that, the scientist must be in close, free and friendly relation with the democratically ordered state machinery, and

the people at large must have an adequate understanding of the possibilities and limitations of science. At present, science is far too much regarded as a mysterious producer of magical results. The object of any attempted popularisation of science should no longer be, as it rightly was in the nineteenth century, to acquaint the public with the mere facts of scientific discoveries. Far more important now is to relate those discoveries to their applications in ordinary life. This is a matter for education and publicity. Science has never taken the place it should in our educational scheme. It needs to be worked in at every stage and related throughout to the interests of each age of student. Far more can be done to popularise science. There is no part of science so obscure and mysterious that it does not have some bearing on current problems. The works of such writers as Haldane and Crowther have shown that it is possible to write of science in the new way with the same popular appeal as that of the great scientific publicists of the last century.

Any realistic picture must, however, point out not only the possibilities of science, but the factors preventing those possibilities from being realised. There is today a growing concern with a better world after the war. But to consider the shape of such a better world without considering the obstacles that lie in the path of its realisation is simply escapism. We can study those obstacles best, not projected in an imaginary form, but here and now.

Private and institutional greed, the desire to preserve orders and ranks in a society that has outgrown them, have been potent factors in the past, and are potent factors still, in delaying progress. Unless they are dealt with, and dealt with now, there is no chance for any better world.

That is the major practical problem of our time, and it is a social and political one. It will be solved by the people themselves. But the technical forms of the solution, and the rapidity with which it will be possible to achieve a better world, will demand science; and for that reason alone the people need to know and to understand, possibly better than the scientists themselves, what modern science is, and how it works.

From "This Changing World" Series 2. (Geo. Routledge, 1944).

SCIENCE AND LIBERTY

THERE is no branch of human activity more dependent than science on the maintenance of liberty. For other occupations liberty is an advantage, for science it is a necessity of its very existence. Trades and professions can continue to exist even if all opportunities for advance are barred to them, for science continual and free advance is essential if it is not to degenerate into pedantry and mysticism. That is why we find in history that while the material arts of life have alternately advanced or stagnated, science has only flourished for short periods and has been all but extinguished in the intervals. Characteristically the great ages of science, those periods where new ideas of the structure of the universe were germinating and the foundations were being laid for radically new technical advances, were also great periods of economic and political liberation. The rise of Greek science was not a mysterious phenomenon occurring by itself, it coincided with the great economic and political struggles which first placed before the world the ideals of liberty and democracy. The decay of classical science came long before the barbarian invasions. The military and plutocratic state of the Alexandrians and Romans, though it preserved material culture for a while, had no place for the adventures of the mind. Classical science suffered also from a more subtle loss of liberty, the fatal separation of the theoretical thinker from the practical craftsman, a separation made absolute by the enormous growth of slavery and the consequent contempt of manual work.

The creation of science, as we know it now, is the work of the Renaissance and coincides with the breaking of the bonds of clerical and feudal restrictions in all spheres. The champions of the new science—Bruno, Servetus, Galileo—were also social and religious reformers. The struggle for intellectual liberty was as much political as scientific. The greatest outburst of scientific activity occurred in our own country in the stormy seventeenth century in which were established at once its liberties and its commercial greatness. The early Royal Society was the first and an immensely successful experiment in democratic organisation in the world of thought. Nor were the early fellows abstract theoreticians like their Greek fore-

runners. Most of them were practical men of business; architects like Wren, navigators like Halley, or jacks-of-all-trades like Hooke. The freedom of conscience and the freedom of organisation won for them by their Roundhead predecessors gave them the opportunity to speculate freely and to come together to test their ideas by experiment.

With the establishment of the commercial and landed oligarchy under the Georges science declined sadly. It reappeared towards the end of the eighteenth century in another field among the rising manufacturers of Birmingham, Manchester, Glasgow and Leeds, and at the same time in France among the forerunners of the French Revolution. The *Encyclopedie*, that bible of liberal thought, was at the same time an attack on privilege and tyranny and a textbook of economics and applied science. The idea of natural laws which Newton had established carried with it the implications of a natural and at the same time rational social order. The close alliance which existed between science and social and religious liberty is epitomised by the careers of such men as Franklin and Priestley. Indeed the decay into which science fell in the twenties and thirties of the nineteenth century was largely a result of the reaction of the wealthy and powerful against its atheistical and jacobin association.

For practical ends science was needed then as much as ever before. It was just beginning to prove directly useful to industry and a means had to be found for getting over this difficulty. The solution lay in a separation of science from the liberal movement carried out by snobs such as Davy or pietistic recluses like Faraday. The idea of pure science was a convenient fiction of the nineteenth century. It enabled the wealthy to subsidise science without fearing to endanger their interests, and scientists to avoid having to ask awkward questions as to the effects of their work in building up the black hell of industrial Britain.

The Darwinian controversy certainly upset for a while the growing social conformity of the scientists; they were forced to choose between championing an officially unpopular and indeed radical view and denying the validity of the methods of science itself. Yet by the end of the century the Church had given in and was willing to share with the scientific pundit the claims to elucidate the mysteries of the universe.

The first world war and its aftermath brought a fundamental change. Science had up till then preserved something of its amateur status through its connections with the universities and with men of independent means. As a Cambridge professor used to put it, "Scientific research is a proper occupation for the leisure of an English gentleman." All this changed when the needs of war and monopolised industry made increasing demands on the scientist's services and provided for him in return the elaborate and expensive apparatus without which modern research cannot be carried out. Science has since then become more and more professionalised. It is recognised as a necessary part of national productive organisation, but this while it brings material advantages is also seriously endangering its liberty and consequently its very existence.

We can see this process in two stages, the insidious disenfranchisement of science in the capitalist democracies and its brutal subjection in the fascist countries. Two of the necessary fundamental conditions for the growth of science have been its freedom from secrecy and its international character. Both of these have already been seriously affected. Industrial or national science tends increasingly towards secrecy. Each concern or each country wishes to secure the advantages of science for itself and the free interchange of ideas and personnel is visibly drying up. In Britain ten per cent of scientific articles of recent years come from industrial or governmental laboratories, though these employ the greater proportion of scientific workers. One can only conclude that these are either not producing scientific work of any importance or not being allowed to publish it—probably both. The scientist in becoming a salaried official is exposed to many subtle dangers. He is no longer finding out things for himself or for humanity but for his firm or his national government. The temptation to find out only what is agreeable or to become a routineer is almost irresistible. On questions of fundamental social importance a few scientists, from the comparative security of academic posts, can and do speak out; the vast majority do not care or are afraid to say a word.

The effect of this enforced conformity, if it is allowed to continue for more than a generation, might well stifle the spirit of originality in science and reduce it to a lifeless assembly of dogmas and technical formulae. Yet this is by no means the

only danger to which science is exposed. The liberty of science is popularly supposed to reside in its liberty of thought. But the scientist thinks as much with his hands and his apparatus as with his brain. It would not be sufficient to leave the scientist free from interference to ensure his freedom in these days; if he is not provided with assistance and apparatus he is as effectively silenced as by imprisonment or censorship. Furthermore, in many fields of science a single man however well equipped can do little, he needs to work in with an organised body of other workers to be effective. Now in this respect science in a country like Britain is starved and ill-organised. Not one-tenth of one per cent of the national income is spent on science, and of what is spent probably more than a half is wasted by lack of co-ordination and by chaotic organisation. In this way the liberty of science is restricted and the fact that scientific workers are so used to it that they do not see what they are losing is but another symptom of the general evil.

Science does not exist in a social and economic vacuum. Research tends more and more to originate in economic needs and, whether it does or not, results sooner or later in economic applications. Much of the stimulus to scientific discovery in the past was the desire for the ultimate benefit of humanity. Now as science is used today to increase the profits of already wealthy corporations, to multiply want and unemployment and, worst of all, to perfect the killing devices of an already well armed state, this stimulus has become to all humane minds a discouragement. The frustration of science as a gift to humanity is itself a powerful retarder of scientific advance. Where these conditions do not hold, as in the Soviet Union, we can witness an immense release of creative impulse in scientific construction for the benefit of all.

Fascism represents on the contrary the logical development of national and private science to the point that science itself is fatally crippled. The destruction of its liberty is complete on all grounds. The scientist is free neither in his thoughts nor in the carrying out of his work nor in the social results that come from it. Science is still needed for the aggrandisement of the state and for the increase of its offensive and defensive potential. Material support is therefore still available. In these conditions such of the older scientists as have not been exiled or imprisoned can continue to work, but their

followers are few and poor in quality. Science has become rather a suspect than a respected profession. Intelligent men of liberal views are hampered at every turn, intelligent reactionaries find more scope in the army or in propaganda. Already in Germany there has been a marked falling-off in both quantity and quality of published work. Even the technical side has been affected though more slowly. The number of engineering students in Germany has fallen by half in the last eight years. Here we can see before our eyes how the loss of liberty entails the destruction of science and the loss of its potential gift to humanity.

The situation in Germany is not an isolated one. Abyssinia, Spain, China, Austria are milestones in the advance of international fascism. The tendencies to these developments are present in our own country. Unless they are checked, unless fascism is resisted and held till it breaks from within, science will not only cease to grow—it will be destroyed as completely as if not more completely than the science of the ancients.

The fate of science depends upon the preservation of liberty. Science has as yet hardly begun to yield the benefits it holds in store for humanity. It has been directed up till now for private profit rather than public welfare. The benefits it has brought have been largely incidental. Even existing science consciously directed and planned for human welfare could transform the world in half a generation. If we are to see this the scientist must realise his kinship with the gathering forces of liberty and democracy and they in their turn must learn to understand and use science in their struggle for a better world.

From *Science and Society*, U.S.A., 1938

LIBERTY AND THE INDIVIDUAL: THE SCIENTIST'S VIEW

A SCIENTIST'S view of freedom is bound to be a little different from other people's; not more different from the average, necessarily, than that of the bricklayer or parson, but different in a way of its own. The scientist comes across the problem of freedom in two extra ways in connection

with his work, first of all in the work itself and secondly in the carrying of it out. A number of the fields that scientists study contain parts that have freedom, or appear to have it—even in an abstract subject like mechanics, we talk about the degrees of freedom of a system—but of course it is much more frequent the nearer we come to systems like ourselves: living organisms and animal societies. Now the kind of freedom that the scientist refers to there, borrowing the word of course from common human experience, is what happens when things move around in a number of rather casual directions, without any perceptible reason why they should go one way rather than another. Freedom appears negative, as the absence of restriction. But a deeper study of all these kinds of systems shows that this freedom has definite limitations. Any individual molecule of a gas is always shooting off in this way or that way until it hits another molecule and changes its direction and speed. But however free each individual molecule seems, the astonishing thing is that the average of the velocities of the molecules is fixed by the temperature—if some go faster, others must go slower, and as a result the gas obeys those definite but rather boring laws of Boyle and Charles: $PV = RT$—a very regular law out of very chaotic behaviour. And so it is with practically every kind of freedom we study. We see that what appears to be complete blind chance on one level of analysis becomes statistical order on the next. This is true also, of course, about human beings. No one knows, for instance, if and when he is going to get pneumonia; but the number of cases of pneumonia follows a definite curve with a seasonal regularity. Even the most unusual things have this regularity. It was first noticed a hundred years ago that the average number of Prussian cavalrymen killed by the kicks of horses was remarkably constant year after year, and yet there were never more than three or four in any year.

But there is another side to this question. If we look at each individual event separately we see it is not so free after all. The movement of a molecule, like that of a billiard-ball, depends on the precise way it was hit by the last molecule it met in the general rough-and-tumble. Whether someone will catch pneumonia depends on a complex but quite definite set of factors—the number of bacteria in the air, temperature, food, bodily constitution, and other things that determine why one

person, and not his neighbour, goes down. In this sense freedom is simply an expression of our ignorance of how things are caused.

Now these contrasting aspects of freedom, each random event being determined by antecedent causes, and the resultant of them being an exact statistical law, give the scientist a kind of two-way freedom, and make him think that perhaps the vaunted freewill of the individual is largely an expression of his ignorance of why he does what he does—one's friends often know much better how one is going to behave than one does oneself; and also that, by and large, people can be counted on to behave in a certain way. Their individual freedoms cancel out, as it were, in average behaviour.

There is another special way, however, in which scientists think about freedom, and here they appear not as observers or experimenters, but as themselves the objects or victims; that is, in their own freedom as scientists—their freedom of inquiry, of publication, and of discussion with other scientists. Of course, this is only part of the general question of the economic and political freedom of the individual in modern society, but it is specially important to scientists. This is because freedom is a necessity for scientists in their work more than it is for most other professions, even perhaps than for the artist. Unless you can examine what you like, do what experiments you like, and discuss them with whom you like, you cannot find out how nature works and how to control it; that is, you cannot do your job as a scientist properly. Now this means much more than the absence of restrictions or secrecy. It is not much use these days to give a scientist a formal freedom of inquiry unless at the same time you give him a salary he can live on without anxiety, apparatus to work with, assistants to help him and facilities for publication and travel. A scientist deprived of these things must feel in some degree frustrated. Without the full positive freedom of work and publication he will be tempted to stick to routine jobs, or to occupy himself in inquiries which, however, intriguing, cost little and lead to nothing.

Another and even more urgent reason why the scientist in these days is concerned with freedom is that more and more restrictions are being piled on him just because it is beginning to be recognised that his work is important, and, if wrongly used, dangerous. The simple equation $e \times mc^2$, which

Einstein first stated forty years ago, which expresses the fact that mass and energy are the same, is a lineal ancestor of the atomic bomb.

So the question of freedom has come to be a very burning one indeed for the scientist of today, and controversies about what it means occur even among scientists themselves. At first sight it seems rather a simple question, and so it still seems to some of our older or more conservative scientists. If science is merely the pursuit of knowledge for its own sake, why, they ask, cannot we return to the state where every scientist was completely free to investigate and publish? But who, others ask, is to pay for it? Science costs money nowadays, a lot of money. The answer given is that the pursuit of truth is an end in itself, and an ornament to the society where it is carried out; society therefore should pay scientists just to discover truth, as it pays clergymen to propagate religion. To the other school of scientists, who see science more as a moving index of change and transformation in society, and firmly rooted in the technical, economic and political development of that society, the freedom of science is something much greater and more complicated. They think of science today not as the sum of the efforts of individual workers just added together. It is much more the product of these efforts multiplied through the working of a system, one in which workers are teamed together in small groups and connected in a wider if looser organisation of science, and it does not operate blindly, but according to a plan.

It is here, in the relation between freedom and planning, that the scientists come across in their own work the general conflict that affects society today, and come across it in a particularly sharp form, because the scientist needs both freedom and planning, and needs to prevent them interfering with each other. He needs freedom for the reasons I have given before, in order to get on with his job and to both give and get the best in relation to other workers. But he needs planning no less, because the success of his work will depend on his having available to him the work of others which he cannot possibly do for himself, and no less for his work to be available for those who want to use it in their turn. The end-product of this chain of scientific work is, of course, the development and production of the things and services by which men live—the food and the goods and the medicines. Now this idea that science will

ultimately be used for human welfare makes some people think that planning of science means that everybody must immediately drop all their abstract researches and get down to curing turnip-fly disease or producing non-creep steel. But the scientists who have really thought about it realise perfectly well that the whole of science is an interrelated organism in which fundamental work on the theory of equations or the structure of chromosomes is absolutely essential to the success of the more immediately applied work. And this fundamental science is also essential for a different reason. What is important for science is not only what is found out, but the way it is found out; and in exploring the underlying principles of science we will discover new methods which can be applied not only in other parts of science, but also in the conduct of our everyday affairs. The scientific method is something that started among specialists, but needs to be extended to every enterprise in modern society. So the real planning of science means finding and securing a balanced but always changing arrangement of every kind of inquiry, from the most abstract to the most concrete.

But there is still an objection which can be raised. Supposing we had an ideal science organisation of this kind, wouldn't it tend to become rigid and unprogressive? The answer is, of course, that it would if it were done the wrong way, that is, the stupid way, of someone making a paper scheme and fitting everyone into his place in it. Actually no one is proposing to plan science in this way. Such an idea only exists in fact in the minds of those who are opposed to planning and want to make a bogy out of it in order to frighten people into leaving things exactly as they are, for the sake of their own comfort or advantage. The alternative to that, and the real way of joining freedom and planning, is democracy; not just the democracy of the ballot-box, but the democracy of the cricket club or the trade-union branch. The only people who can possibly run a plan for science are scientists, because they are the only people who know what it is all about. But it cannot be left to the august and senior scientists, who are much too busy, even if it were humanly possible, to attend to all the details. It must be something like the soviet system—a group of scientists in a laboratory making out the scheme for the work of that laboratory, and building up, from a somewhat informal network of ideas, some general kind of plan. We have got

something like that now, but it is very unbalanced and untidy, and the need for science is so great that we are already being forced to put it into more shipshape order, and to get on with the job of science with much greater intensity and effectiveness.

Now, perhaps, you can see something of how the scientist's experience can contribute to the general discussions of liberty and the individual. The freedom of the scientist is not an anarchic freedom, but an ordered freedom, in a self-chosen order, and thus really what we are all trying to get at in the wider world. The problems of the planning of science are met with again on a larger scale in the planning of industry and the state. We have had, in the war, some foretaste of the degree in which the whole of a common effort could be planned and carried out scientifically. Indeed those of us who had that experience have seen possibilities for willing and effective human collaboration that before then we had considered utopian. One fact that impressed all of us was the importance of getting the most out of every individual by seeing that he was doing a job he wanted to do and that he was given the best conditions for carrying it out.

The realisation that the individual can only get a satisfactory life in a society which is so ordered that these conditions are satisfied can be reached in many ways. It has been for over a hundred years the guiding principle of socialism, but recent experience and analysis shows that it is also the only scientific way of arranging society. To order people about is to get less out of them than they would give willingly, and to lose all the advantages that are to be gained from the exercise of their judgment. To allow people an illusive freedom to compete with and struggle against each other for a livelihood limited by their incapacity to co-operate is almost equally inefficient, because here, although we are using individual initiative, it is being used in a way where it largely cancels itself out. Men have felt for many thousands of years the essential injustice which comes from inequality and slavery. To that feeling of injustice we can now add the knowledge that these practices are also grossly inefficient and destructive. The horrors of the industrial revolution, with its absolutely unfettered competition, were a by-product of the reaction from the ordered but grossly unjust system of the Middle Ages. The liberty of the individual is something which depends absolutely on the

securing of the best relations between that individual and the other individuals that make up society. To feel really free, they must be working together, not against each other, and must form part of an order; but they must feel part of that order, and not have it imposed on them, even for their own good. To feel the order they must understand it as well, and the understanding of society, or, as we would put it, the pursuit of the social sciences, is just as essential a factor in securing liberty as are planning and democracy themselves.

Broadcast, December 1946

SCIENCE AND THE HUMANITIES

INTRODUCTION

THE essays in this section are mostly concerned with the relation of science and education. The first two deal with the related problems of the part taken by science in general education, and the part that needs to be taken by the humanities in scientific education. Together in a complementary way they emphasise the danger of one-sided education in a world of the technical and social complexity of today, and offer some practical suggestions as to how this may be overcome. The other two essays are of a different character in that they deal with the different contributions of two great educators, Comenius, the Czech patriot who was the founder of modern education, particularly in relation to his influence on England, and Shaw, whose clear and inspired common sense penetrated the hypocrises and falsities of science and education as much as it did the social habits of Victorian England. The whole tendency of these essays is one towards a unified culture in which science and the humanities play equal and complementary parts.

SCIENCE TEACHING IN GENERAL EDUCATION[1]

ONE of the most welcome features of the modern educational movement is the interest that is being taken in the objects of education. The basic question of why we are educating children at all has to be answered in the process of finding the most effective educational methods. The search for objectives has been made necessary by the emergence of two important developments; one is the policy of educating the majority of the population up to late adolescence, and the other is the growth of the field of science. Science has so developed that it

[1] This paper is an elaboration of a discussion at a round table on the Social Function of Science under the auspices of the Progressive Education Curriculum Workshop at Sarah Lawrence College, New York, August 1939.

can no longer be considered as a mere adjunct to a general humane education, but rather must take its place at the centre of any educational scheme. The old methods of teaching, with their formal approach, and their rigid separation between science and the humanities, are plainly incompetent to deal with these developments. The attempt to apply them results in parrot-like learning, in a stifling of intelligence and criticism, and in the production of individuals who know so little of the major factors affecting their lives that they are more at the mercy of demagogues and quacks than an illiterate population. And these tendencies can no longer be dismissed as harmless. We have seen in the last few years that a people such as the Germans, who have received the best education on traditional lines, can become more of a danger to themselves and to the world than any savage or barbarous nation. The reform of education is not a luxury, it is a necessity if we are to safeguard existing democracy and make possible its development into a more effective means of human co-operation.

If science is to take the central part in a new educational system, it must be a science that relates far more closely than in the past to the material and social aspects of ordinary life, and it must be linked throughout with the other parts of teaching. The methods of science teaching have grown up in the past out of the need to provide training for science specialists: doctors, engineers, chemists, or geologists. As science teaching spread, these training purposes were minimised, but they were never abandoned. The dominant aim was still to impart necessary information and standard techniques. At its best, this method would provide for competent specialists. At its worst, it simply handed out information that was so out of relation with life as to become meaningless and impossible to remember. In the new view, training in science is required for two purposes:

The first objective is *to provide enough understanding of the place of science in society to enable the great majority that will not be actively engaged in scientific pursuits to collaborate intelligently with those who are, and to be able to criticise or appreciate the effect of science on society.*

The second objective, which is not entirely distinct, is *to give a practical understanding of scientific method, sufficient to be applicable to the problems which the citizen has to face in his individual and social life.*

It is this latter objective that has been so completely neglected in the science teaching of the past, and which now requires the greatest thought and attention. What we have to do is to get across, no longer a certain number of scientific facts, but what may be called the operative content of science. The amount of knowledge needed for doing things is kept alive and memorable because it is constantly being used. With the operative content, and inseparable from it, should be the method of science which includes both the aspects of discovery and criticism.

How is the science teacher in practice to effect this change in educational objectives? Here it is no question simply of applying known methods to other than accepted situations. The methods will have to be worked out in practice by the teachers themselves. If the science teacher hopes to be able to bring the teaching of science more closely into relation with ordinary life, it is clear that he must himself take a larger part in that life. His functions must be enlarged to include the study and the criticism of the attempts to modify the social and material structure of the community in which he works. This would seem to be at first sight an intolerable burden on the teacher, but the experience of those who have already been attempting such activity shows that the wider view of science makes it more real, and consequently more easy to understand and to remember. There is all the difference in the world between studying a subject with the object of imparting it to a class, and studying it as a means of helping to solve with the class some immediate and important social problem. The full significance of science is, in fact, impossible to grasp without a knowledge of its past, present, and future relations to society. The central problem is one of integration, but not of formal and meaningless integration, such as would be confined to statements that all aspects of knowledge are related to each other, but in precise detailed and practical relations between the particular skills of the scientist, the historian, and the common-sense and practical views of the community outside the school.

The position of the science teacher in a community is peculiar only in that he will usually be one of a few or even the only one to possess certain kinds of specialised knowledge. He will understand, for instance, the physics of erosion processes, while others appreciate as directly their economic and social

destructiveness. It is through the possession of this special knowledge that the science teacher acquires his special responsibility. Until recently, we have too often taken the ivory-tower view that the possession of knowledge was a purely private affair and that at most it involved the responsibility of imparting that knowledge to any that might ask to share it. We now feel that knowledge is a possession which is being wasted if it is not being continually used and tested and we may even doubt in this case how truly it is knowledge and not mere pedantry.

A central factor of our civilisation today is that we possess through science enormous possibilities for human betterment, and that these possibilities are not being used for that purpose, and often enough for the very opposite. It is the responsibility of the science teacher to point this out, but in order to do so we must have the necessary knowledge of how the processes and results of science are linked with society, and this involves a much closer collaboration with the humanities and particularly with history than has yet taken place. We may frankly say that we do not know today what are the effective relations between social-economic development and scientific discovery, but we are finding out and we can see already that the old picture of science as an almost impersonal force, discovering new truths which can then be applied to practical things of economic value, is only half the truth, and as such gives an entirely false picture.

Society influences, inspires and directs science quite as much as science transforms society. All of the great discoveries and inventions of the past—the telescope, the steam engine, the theories of gravitation and of evolution—are themselves just as much products of society and economic forces as they are factors in social change. The history of science must become a vital part of science teaching, and on the other hand, the understanding of science and of its social importance must enter into all historical courses. It is now possible to present, at any rate in outline, a picture of human development in which science plays an understandable part and provides a clue for many of the transformations which have been the mainspring of vast political and economic changes. We see in particular that the confusion and struggle of our own times is largely the result of the inability of an economic and political system which grew

up in an era of small trading and handicraft industry to deal with the new possibilities of large-scale mechanised industry and transport, which by their very nature imply a far more highly organised and planned society.

The greatest defect of scientific education in the past has been its inability to transmit the most characteristic aspect of science, namely, its method. This was to a large extent inevitable, given the fact that few scientists or science teachers understood this method, and that those who did understand it were too occupied to teach it, except by personal contact and inspiration. What has passed for scientific method is an abstract made by philosophers of the old school and it has never contributed anything to the advance or to the understanding of science. Now, just because we do not know what the method of science is, we have no excuse for not teaching it, for the ability of learning to do things can well precede the analysis of the processes involved. *It is most important that all, and particularly those who are not continuing in scientific careers, should learn scientific method by practising it.* This practice is far more valuable than an accumulation of facts which, even if remembered, cannot be put to any use.

We have had in the past the greatest confusion as to the very meaning of the scientific method. In most presentations it appears as a means for arriving at truth by carefully sifted evidence on which is built a structure of inductive or deductive logic. Such a presentation is false because it does not represent perhaps the most characteristic aspect of science, its ability to seek and discover new significant relationships, which must be found before their validity can be tested. No exercise of logic can discover the scientific method. It must be treated like every other object of study, by examining what people actually do when occupied in scientific research. The teacher can only bring out the processes of discovery by practising it. The business of finding problems in situations, of formulating those problems, of solving them, and of checking the results, is something that can only be appreciated by those who have carried it out. Only on this basis can the work of the scientists of the past and the present be effectively understood. Every science teacher and every science pupil must be to some extent a research worker.

The spread of the problem approach to schools indicates that

this aspect is being understood, but it is a new technique and it will be necessary to learn much about its possibilities and limitations before it can be confidently accepted as a solution to the major problem of science teaching. For a problem to be of value in getting scientific method across, it must be at once interesting, significant and real. The interest of the problem can only be judged by those who are tackling it. The fact that the problem interests the teacher is of minor importance. It would be far better, if it were possible, that all problems should originate among the pupils themselves and arise from situations which are familiar and important to them at the various stages of their development. Although it would be pedantic to insist that all problems should have a certain significance, for there is plenty of room for trivial and merely amusing problems, it is important that the majority of problems should mean something in the lives of the pupils or of the community in which they work. The story of the school that built a Roman galley in its dry backyard, while in front of it lay a hillside visibly eroding, may stand as an example of the need to turn from a type of education intended for dilettante gentleman to one of social utility.

Finally, the problems must be real, that is, they must be ones for which the answer is something honestly sought, and not already known or supposed to be known to the teacher. Faced with an unreal problem, the pupils very naturally turn it into a real one, which is to find out what answer the teacher wants them to get, and that attitude prolonged through life creates the mass of yes-men and place-holders who are the most effective blocks to real social advancement.

Devotion to problems should not, however, take the place of a comprehensive curriculum. It is clear that the detail in which a problem must be studied will prevent a whole field being covered by such problems. They must be considered frankly as samples, but if no problem is treated in isolation and each one is allowed to branch off enough to indicate related problems and related fields of study, it should be possible to provide enough of the outline of general scientific knowledge to enable any new problem to find its natural place. For example, the problem of methods of heating and air-conditioning may well involve the whole theory of heat, and link up with problems of heat engines and of climate.

We are still very much in the dark as to what the ideal curriculum for science should be. It is clear that it should vary far more than it has varied in the past from age to age, and community to community, and also that it must keep pace more closely with scientific advances. It is not so essential on their own account that people should learn the latest discoveries of science. Many earlier discoveries were of far greater importance. The value of teaching recent work lies rather in the very fact that it is recent, that science appears not as a storehouse of knowledge to be accepted on authority, but as something continuously changing and being revised to meet new knowledge and new needs. If at the same time pupils have learned through their own efforts to make additions to knowledge, however small, they can identify themselves with the processes of science, rather than rest content in a finished temple of science.

In the older methods of scientific education, where the training of the specialist was the aim, it was considered necessary that everyone should acquire certain particular techniques, such as those of precise measurement, of chemical analysis or of classification. The time and effort spent on these and the general boredom they inspired was one of the most effective deterrents to real scientific education. It was not grasped that most people, except for certain rather odd psychological types, learn techniques to use them and not for their own sake. By not attempting to teach these techniques, the effective time available for science teaching can be much increased.

But this does not mean it would be desirable not to teach any techniques at all. There remain a number of techniques which are not generally known and yet are of the greatest value in everyday life. The teaching of these might at least in part take the place of the earlier techniques. Every citizen of today ought to understand enough of the use of graphs and of probability calculations to make sensible choices as a consumer and to be able to reach a balanced opinion in making economic and political decisions. We particularly need some picture of the maximum set of such techniques that we can expect to get across in a general educational system, but it is certain that the qualitative type of argument used in science will form part of it and be an effective deterrent to the acceptance of the majority of emo-

tional arguments which are now being used so successfully to confuse and enslave whole populations. Needless to say, such techniques are not to be learned in the abstract. They must be demonstrated in situations resembling as closely as possible those of ordinary life, so that requirements of transfer need hardly arise.

The central problem of making science an effective possession of the whole people cannot be sought merely by changes in curricula or teaching methods. A new relation between the science teacher and his pupils and between both of these and the community are necessary. These changes are in line with the general development of ideas in education. How can we expect to build up a democratic community if we do not give opportunity for the practice of democracy from the earlier stages? Particularly in science, where what we want to bring out is the danger of authority and the need to question everything, it is absurd and self-defeating to use authoritarian methods of teaching. Actually, experience in a number of schools has already shown that scientific processes and scientific thinking are not themselves peculiarly adult attributes. Given a suitable environment, children almost from infancy can argue as reasonably and can discover as originally as any adult. The fact that, owing to their limited field of experience, their discoveries have usually been anticipated should not prevent us from appreciating and using their capacity. In the last few years, we have seen in England that the most intelligent drive for reform of science teaching has come from the students. What is not usually recognised is that the educator today, particularly in the cities, is called on to provide a situation to take the place of the older traditional upbringing of children on farms and in villages. Here children both observed and took part in practically every adult occupation, while now the environment is becoming increasingly divorced from such occupation, and it is the responsibility of the school to provide for it. Mere lessons and academic exercises are not substitutes. The pupils must themselves be doing something which they can feel has real social importance. The failure to do this is reflected in adult society by an excessively narrow attitude towards human occupations where work is considered an unpleasant necessity rather than an essential and satisfactory part of social life.

If the school is to provide the objective surroundings which are to take the place of those of the village community, it is clear that the social responsibility of the teacher is much increased. The teacher in the past was not strictly an educator. His business was to see that the majority of his pupils knew how to read and write, and that a few gifted ones could be trained for the professions and the ministry. The main burden of education fell on the farm and village. Now, however, the teacher, particularly the science teacher, has to provide for the understanding of and the participation in a vastly more complex social and economic organisation. He is obliged, if he is to fulfil his responsibilities, to understand that organisation, and to lead his pupils into an effective mastery of it.

This means that he must concern himself with immediate practical social problems. Now the essence of these problems is that they are controversial. Here we meet the most fundamental difficulty of how the teacher is to deal with controversial issues. The older traditional education had it that he must retain a strict impartiality, but to do so under modern conditions would mean that he was unable to help his pupils in any way to deal with their real problems. The human applications of scientific knowledge are as much part of science as its theory. We do not expect the science teacher to retain an impartial attitude with respect to a flat earth or a special creation of organisms. But the problems of nutrition or erosion admit just as little of an impartial attitude. Impartiality is not objectivity, it is simply a refusal to look rationally at awkward issues. If people have not enough to eat to keep healthy, the science teacher must point it out and either he or the social science teacher will be obliged to discuss how and why such a situation arises, and what can be done to remedy it. To do less would be to admit that science was just a play of words and would inevitably create in the minds of students the idea that it was an ineffective adjunct to life, instead of one of the major agents of social change.

We must naturally realise that under existing conditions it will not always be easy for the teacher to take a definite line on such questions. Anti-scientific and anti-social forces are powerfully entrenched in the school system, and the approach to social problems may have to be indirect and should always be tactful. But the essential thing is that the teacher should

understand the situation and know what he is striving for. The means he uses will depend on the circumstances. We have seen in England the success that has attended the persistent efforts of school teachers and doctors to see that children in schools receive adequate nourishment, and this success has been due, very largely, to the ability of the school teachers to demonstrate their case scientifically. If a school science teacher knows his job, he will sooner or later be able to convince the community that a rational approach to social problems is not either radicalism or idealistic philanthropy, but plain common sense, and if at the same time there are good working relations between teacher and pupils, the task will be made much easier and shorter.

It would be foolish in dealing with developments of education to ignore the very serious obstacles that stand in the way. The modern movement is particularly exposed to criticism, most of it ignorant and prejudiced but some of it having substantial justification. The advantage of any traditional method is that it does what is expected of it. Older teaching may not have produced either educated or reasonable citizens, but it produced the kind of citizens people were accustomed to. The new education suffers under the disadvantage of being experimental and aiming at new things. If, further, it occupies itself with social and political implications of knowledge, it opens itself to far more serious attack. But these attacks will have to be met, for to surrender to prejudice, even in part, can only lead to a compromise system which would have the disadvantages of both the old and the new. The two essentials are that the student educated the new way should have all the practical competence in the techniques of life that belong to the student of the old school, and at the same time that he should not feel less but more able to play an acceptable and effective part in society.

The first problem is to see that the application of the new educational methods is sufficiently intelligently thought out, so as to cover the essentials of knowledge which are required to meet the practical tests of the traditional methods. This is not so difficult as it might seem, because much of traditional learning is useless and difficult to remember and the actual amount required is much smaller than that which was taught. Nevertheless, in working out a curriculum, particularly using

the problem method, it is essential to plan so as to cover the field in a comprehensive way.

The second requirement, that of the social ability of the students of the new school, is one more difficult to satisfy. It is inevitable, as long as modern schools are a minority, that the students should feel themselves different from others, and being different, even if it is an improvement, is always a social disadvantage. The remedy for this is to see that the pupils are not cut off at any time from the society in which they live, but take an even more active part in it than do those of older schools, or that they are not encouraged to think of themselves as receiving a special or superior education. The more spontaneous, democratic and important student life is, the less likelihood of the creation of any feeling of superiority.

The problem of the social and political line taken up in the school is a serious one. In many places, school boards of directors consider that they are hiring teachers simply to perpetuate the existing situation in the community, with all its peculiarities and prejudices. The teacher cannot acquiesce in this view without sacrificing his scientific integrity. He is not so much a representative of the particular community or of its socially dominant members as he is one of that general human culture which it is his duty to transmit. There need not be, and there should not be, any open conflict, if the teacher can hold to his own ideal and see that it is understood and appreciated. There is no question of the teacher usurping the position of the religious preacher or political leader. His business is to present things as they are and to indicate what can be done to improve them. He is not called on as teacher, though he may be as citizen, to take any active steps, but he cannot as teacher fairly remain silent or refuse to examine and to discuss the relevant facts of the situation.

To define the field of relevance is more difficult. Natural and social science now overlap to such a degree that it is difficult to say whether such questions as nutrition, soil conservation and technical unemployment lie in one field or the other. The important thing, however, is not who should teach about these things, but that they should be taught by somebody. Ideally, close collaboration between natural and social science teachers can produce a balanced presentation, but failing that, one or the other could equally carry on this task.

It is sometimes claimed that the extension of the field of science to cover practical and social considerations puts too much of a burden on the teacher, but those who make this claim have usually little acquaintance with the practice of such an extension, or they would know that an appreciation of the social significance of science greatly increases our understanding of its principles.

The new principles of education reflect the movement which rejects the necessity for the present chaotic, insecure and thwarted state of human society. The development of science has provided us with the means for a fruitful and secure life. The obstacles to that life are no longer material ones. They lie in social forms, and in the attitude of those who from interest or stupidity are wedded to those forms. The world cannot advance, indeed it cannot carry on without a far more conscious and ordered handling of social and economic matters. If we fail to educate people to think about this, our present difficulties will grow worse, until they culminate in the miserable serfdom of fascism, and the wars which are fascism's only answer to the difficulties they cannot cope with. Science and education are still powerful weapons for the defence of democracy, and for making possible the extension and development of democracy in the direction of an ordered, yet free, co-operative community.

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SCIENCE AND THE HUMANITIES

FOR many years now a division has been established in our universities between the sciences and the humanities. This division is probably more absolute now than it has ever been before, because it is practically impossible for a student to study subjects in both fields simultaneously, and the number who study them successively is negligibly small. This division is probably wider in Britain than in any other country in the world, because we have, for historic reasons, chosen to limit what we call the sciences to what are more properly called the natural sciences, excluding considerations of human society,

however scientific, whereas almost everywhere else the conception extends to all aspects of human knowledge which require the discipline of scholarship in their interpretation.

We are as citizens now engaged in an attempt to supersede the chaotic and inhuman competition of earlier days by a democratically planned community. This makes it all the more necessary to have among those who will administer and direct this transformation men and women whose knowledge of the universe is comprehensive and not one-sided. For this reason the separation of the training of these men and women into watertight compartments is not only deplorable but dangerous, and it is one of the most serious and urgent problems of the univeristies to look for ways of ending it.

This great division in human culture, though produced in its present form by historic and social factors dating from the Renaissance, has much older and deeper roots. Indeed it can be traced back to the earliest stages of human evolution. In early society there was already an unconscious distinction growing up between practical activities depending on direct manipulations of material objects, and the equally effective but quite different emotive appeals for social co-operation. Actions and words, facts and feelings, have stood in human history always in some degree of opposition. In early times magic was a universal solvent for these distinctions. Magic controlled the real world by words of power, but magic likewise could control the human heart, and even the invisible spirits, by manipulation of material magical objects. Primitive man's outlook on life had a unity that ours has not recovered. The loss of that unity was itself an expression of the break-up of society into a ruling caste, which dominated men by words of power, and a working caste, the base mechanics who worked with their hands to produce food and goods. The widsom of the rulers was naturally the higher wisdom, the wisdom of thought and words; but the mechanics and rustics too had their mysteries—the mysteries of the trades, the way in which things had to be done. The rulers had thoughts and souls—they were the people of the spirit. The workers had their hands; they were the body. This distinction between soul and body, spirit and matter, with the implicit superiority of the former, runs through the whole of recorded history, and only began to be questioned in the time of the Renaissance, when the interest

in the body and in the works of the hands showed itself in art, manufacture and trade.

Francis Bacon gave us the first fully explicit expression of the new tendency, with his emphasis on the power of knowledge to improve the material status of man. Descartes at the same time gave us the clearest definitions of the spheres of matter and spirit, removing all but the last vestige of magic. To him there were two worlds, the world of pure thought in which God could be deduced by simple logic, and a material world of extension and time in which determinist laws held absolute sway. He managed to accommodate himself to both together through the somewhat childish conception that these worlds connected together through the pineal gland of the human brain. This compromise satisfied few other minds, and from then on the dualism of mind and matter in philosophy became consecrated. The chain of philosophic thought, through Spinoza, Leibnitz, Locke, Hume, Berkeley and Kant, struggled with this problem but did not advance it, and only succeeded in showing the extreme difficulties inherent in such a split world.

Strangely, the first clue to the solution came from one who was outside this main stream, from the Neapolitan Giambattista Vico, who from his classical and almost mediaeval education, after first espousing, reacted violently against Descartes. Vico's work is the most pertinent to the subject of this discussion, because he saw there was not only one science, but two. In his New Science, full of absurdities as it is, absurdities which he could not fail to draw from his legendary sources, he did express a new and immensely important concept. He divided the world into the world of nature and the world of man, and conceived the world of man in its widest aspect, not only that of history and philology, but of all the arts. He was the first to see that the expression of men's reaction to their universe and to each other is conditioned by the social and political character of the times they live in; that the development of poetry from epic to lyric is a social as much as a metrical development. But his fundamental and great discovery is, as he expressed it, "that the world of man, because it is made by man, can be understood by man." To be fair, he also said that "the world of nature, being made by God, could not be understood by man." Vico died a disappointed man. He felt he had dis-

covered a great secret, and that no one had appreciated it. In fact Vico's ideas, though slow to spread at first, were to have a momentous influence on later human thought. Through Michelet they became an influence in the study of history; but, far more important, through Hegel and Marx they came to provide a new concept of the place and function of man in the universe.

Nevertheless we must admit that, in this country at least, the Cartesian dualism and its parallelism in the cultural field, the distinction between the sciences and the humanities, has provided the basic thought-pattern on which education has been moulded. It is a profoundly unsatisfactory pattern, because it can only be sustained either by ignoring, on the side of science or of the arts, at least half of human experience, or, if an attempt is made to combine them without unifying them, by the obligation to maintain unrelated compartments of thought and consequently to split and diminish the human personality.

The unitary view, on the other hand, largely because the whole trend of teaching is against it, is much more difficult to achieve; nor has it yet acquired a fully explicit formulation. Nevertheless it is a view on which are converging the dominating tendencies of the arts and sciences of our time. On the side of the arts, the human and consequently the social aspects of creation are being more fully recognised. We are gradually emancipating ourselves from a type of criticism that uses associative words like "beauty" or "form," which are merely ways of expressing the approval of something by a culture or even by an individual. Art is now seen more as a form of social communication, as a generalised language through which the artist expresses not a mystical and unique personality or experience, but the sum total of the effects that the society in which he has grown has had on him, and transmits them in a way that affects the society of the future. The creative function of the artist lies in the work, which may be largely unconscious, of selecting and welding together past experience in new ways, and in his success in touching the affective responses of those who see or hear or read his work. Human experience is so vast and complex that it is only through art that its essential motifs can be felt in unity.

This, of course, was well recognised in the past. The poems of Homer, the books of the Bible, were considered divine

because they contained not only a picture of the world of nature, man and gods, but a song that moved and stirred people to action; action that conserved and extended that of the heroes and the peoples of the past, and engaged the living in one common and continuous effort. The creations of art, the heroes and the gods, are made real by just these moving qualities. But the groundwork of the poem is the works and days, the practical material and manual basis of the civilisation. Homer and the poets of the Bible could achieve what they did because the civilisation about which they were writing still remained largely comprehensible and unitary. Once it split into aristocratic and menial sections the possibility of this achievement was lost. The great mirror was broken, but the pieces of it could still reflect. The Bible retained its power to move civilisations which had come into existence long after its own time, largely because, unlike the noble and learned works of the ancient world, most of which were allowed to perish, it retained to the end its essentially popular and, indeed, combative and democratic character, treating of princes but having more regard to the law and the people.

The function of science, though as old, was always different —the function of the maker and not of the seer. Science is usually represented in its aspect of understanding, but what distinguished science long before it was verbal or even conscious was that it indicated ways of doing things that worked. Any understanding, any expression which was not in the last analysis a recipe for successful action was art or magic, but not science. Science also deals with human experience, but it deals with it in a different way. The clue which science followed was that by noticing the connections between things, connections independent of will and unaffected by emotional appeals, it was possible to manipulate the world for desired ends. From the mysteries of a predynastic gold-worker to the paper on quantum mechanics of today, every scientific expression is an indicator. It says, "Look," and it says, "If you do this, that will happen." Of course the poet and the artist also say "Look," but for a different purpose. They point to provide a motive, not to indicate a path.

Now the distinction between the natural sciences and the humanities, though it depends on that between the specific character of art and science, is more complex. Every human

achievement is a unity and contains the aspects of both art and science. It happens simply in some that the aspect of the artist is predominant, and in others that of the scientist. Every work of art inevitably contains a deeper understanding of reality; an understanding which is essentially scientific. In so far as the artist sees clearly he will discover new relations between elements of experience, natural or human, and those are contributions to the sum of scientific knowledge. This is, of course, particularly true now in the human field. Just as the poets of the heroic age are our best sources for the knowledge of nature, so in modern times the novelist may be the best analyst of social and psychological problems. But just as the artist cannot help being a scientist, the scientist cannot help being an artist. Every expression of scientific knowledge, every path of discovery of new facts in nature, is in itself a work of art, itself a product of social mutations and capable of moving in its turn. It has long been noticed that the great scientists are themselves masters of prose, and contribute quite as much as the artist to moulding the emotional tone of their times.

When we think, however, of art and science as human enterprises, we abstract those parts which are foreign to their main purpose. The beauty of prose or of painting is considered as the main objective of the work of art, and the information it gives the secondary; and similarly in science we do not dwell on the form of the discovery, but its content, the very minimum of new and permanent contribution to the cumulative total of human operative experience. Now in this lies a different and real distinction between the arts and sciences. Both are parts of a continuous human tradition. Artists influence each other; art forms are created, flourish and die. The products of art can be divided into schools dominated by some new form of expression. But the tradition of science is all this and more. It is cumulative—it is not a series of successive expressions. It is one total expression of human knowledge; an expression that has continually to be revised and reformed in detail, but one where, with every change and pruning, the stock remains more secure. It is because of this cumulative nature of science that the work of the individual is less regarded. He may be honoured, but he is not read. It is the individual work of the great artist, on the other hand, that survives. The artists are in a sense all contemporaries, while the scientists are successors.

The major difficulty in the way of establishing closer relations between science and the humanities, and of viewing them as part of a union of human knowledge and achievement, is this mixed character of both disciplines. The fundamental distinction between the scientific and the aesthetic mode is apt to attach itself to the practical distinction between the fields of natural and human experience in which both modes can be exercised. This applies even more to teaching than to research or appreciation. The teaching of the humanities has a very old-established tradition, a tradition probably quite continuous from the times of ancient Egypt and Babylon. The methods have been gradually modified, but old principles and lines of division still remain. The starting-point of the humanities is literary, the ability to read and write, and particularly the ability to read and write in the sacred languages. The aim of a literary education has been effectively the acquiring of traditional culture by the methods of scholarship, and the teaching has necessarily concentrated more on the method than on the content, because many lifetimes are really required to absorb the content of culture, whereas there is some reasonable hope that the methods of scholarship by which the content can be reached might be acquired in a few years.

To this old core of literary scholarship has been grafted at various times, in the days of Periclean Athens and later in the Renaissance, an entirely different educational aim, that of producing the citizen or gentleman; an education largely in manners and attitude, in which a knowledge of ancient models is taken to play the chief part. The Chinese classics from Confucius or even before were designed for the same object of producing the scholar-gentleman-administrator. A great deal of this type of education depends on its common acceptance—the right thing to do and the right thing to say is the thing that the best people of the time have the habit of doing and saying. Education itself becomes the hallmark which it is impossible for the uneducated to forge.

Now the full value of this type of education was disappearing even in the nineteenth century, and it showed its last efflorescence in the days before the first world war. With the passing of the gentleman as born ruler, the liberal education of the gentleman lost its object. But the loss of an object is no deterrent to an educational system which has an inertia demon-

strably greater than almost any other human institution, even the laws and the churches. Euclid's elements have held undisputed sway among school-teachers from 300 B.C. to the present day. And of course it is also true that an education ideally aimed at producing gentlemen was, in fact, during most of its course, producing far more minor lawyers and clergymen. Now, with the prevalence of popular literacy, the educational system itself becomes largely the objective of humane education. Teaching is aimed at producing teachers. The means and ends in the humanities are by now hopelessly confused. There was a time when it was very coveniently believed that learning itself was a valuable discipline, training the mind and strengthening the memory, and the uselessness of the thing learnt was of additional value because it proved the disinterestedness of the scholar. The excuse has gone, but the habit persists. What has happened in fact in the humanities is a gradual and reluctant abandonment of the purely classical tradition, and the extension of its methods to cover modern studies such as history, economics and literature. The teaching of the plastic arts and music, being largely manual, falls outside its consideration.

The course of scientific education has been very different. In the first place, until the nineteenth century it was essentially a voluntary education, where people learnt for themselves, either because of a passionate curious interest, or for expected benefits. Medicine, which began being taught as a humanity by lecturers who could not sully themselves by actually touching patients, only later acquired the status of a scientific study. But the object of science was ostensibly successful practice, and, if possible, the advancement of science itself. The content predominated over the form. There was little claim to build characters, but rather to produce adepts. Naturally when it became part of the curricula of schools and universities many of the vices of the older education gradually introduced themselves into scientific teaching. Nevertheless there always remained the test of practice and the intrinsically revolutionary nature of scientific teaching, inculcating doubt in tradition and reliance on direct observation and experiment. The real weakness of the scientific education, particularly in England, was its extreme narrowness. This is in part a legacy from the fact that science had its birth in England at a critical period in our national history, just after the conclusion of the struggle

between King and Parliament. It was natural then that subjects of division and controversy should be omitted from the new science. As Hooke put it: "Not meddling with Divinity, Metaphysics, Moralls, Politicks, Grammar, Rhetorick, or Logick."[1] Unfortunately, owing to the inertia of human institutions, particularly when confirmed by charters and endowed with venerable attributes, this distinction has been allowed to remain long after its utility has passed away. Limited as the fields of scientific research are, in education science has become even more narrowed into mathematics, physics and chemistry, and a very much weaker branch in biology, for the most part attached to medicine. What this now meant was that while humane education wasted a great deal of time on comparatively trivial grammatical and linguistic skills, it did aim at a comprehensive, if traditional and wrong-headed, view of the totality of human experience. Scientific education, on the other hand, gave a much more accurate and progressively approximating view of an extremely limited field. The worst of it was that what was left out in scientific education was what most concerned the student as a person—the knowledge of society and its history, of philosophy, art, religion and morals.

This vacuum could be filled in either of two ways. The conventional way was to leave the scientist to accept the views traditionally held in the society in which he had grown up—and this is the important point—by giving him an education that in general did not enable him to criticise them. This put him at a disadvantage compared with the arts student as a human being and a citizen. The other alternative, available only to strong spirits, was to attempt to apply the principles of scientific method to other fields of experience, usually leading to a complete rejection of tradition and to a nihilist or at least agnostic attitude towards beliefs which could claim no other support than the authority of tradition. To take such an attitude demanded exceptional moral courage, and was therefore attempted by few. It also demanded from each individual the almost impossible task of assessing for himself, without the guidance of tradition, the full relations of man to society. Only if the scientist had the leisure and inclination to be a humanist as well could these difficulties be overcome, and even then it was much more probable that the extremely difficult effort of

[1] Manuscript volume of Hooke's papers dated 1663.

harmonising the humanist and scientific traditions would not be made, but rather they would be allowed to grow together as completely different parts of the personality. Very few, even of the world's greatest scientists, got as far as this. Leonardo da Vinci probably did. Newton and Faraday certainly did not. On the humanist side, the efforts were even rarer. Goethe gives the nearest approach to a humanist who tried to assimilate science, and his science was so coloured by his emotions that it had no effect on the general stream of scientific thought.

The integration between the scientific and humanistic viewpoints is, in fact, a task too great to be imposed on the isolated human mind, even for the greatest of them. It is something which will work itself out in practice in the need to meet and solve the very problems that the disharmony itself creates. This was the way which Marx, himself a humanist turned scientist, saw it in the nineteenth century, and the way in which it is working itself out in country after country in our own time. Education, if it is to rise to its task, must attempt to bring these aspects together. This is not to be done by preaching any cut-and-dried philosophy; still less by reverting to the teaching of philosophic and religious views long outgrown and irrelevant to our modern world. On the contrary, the joining of the two streams of human culture is something for the future, for which we can prepare in education by bringing together in the minds of the new generation the different aspects of the picture, and leaving it to them, first unconsciously and then consciously, to promote the necessary fusion. What we have to do is to design teaching so that the various aspects of human knowledge and human feeling are presented fairly in a balanced way, and with due indication of their interrelationships: that means, naturally, including in education the presentation of interpretations and attitudes about the major current problems, but allowing them to appear as they really are, as debates and not as dogmas. It is, for instance, astonishing that in our universities nearly a hundred years after the appearance of the Communist Manifesto there is no official presentation of the Marxist philosophy, one of the major factors in the thought of our time. The result is not that we have fewer Marxists in the universities, but that the real business of serious education goes on outside and not inside the lecture-room and tutorial.

Bringing the vital subjects of our time into debate in the

universities will help to emphasise the range of necessary knowledge without which they cannot even be grasped. Most people of our time, even the most learned, are in fact grossly uneducated; that is, they are completely ignorant of large sections of the common heritage of culture. They neither know the facts nor the languages in which those facts are expressed. We must at least attempt to provide this background to all our university students. What it is has been adequately put forward by Professor Dobree.[1] The educated man, he says,

> should know something of six different though interconnected realms of intellectual activity: (1) The physical structure of the world he lives in—physics and astronomy; (2) what sort of animal he is, what made him what he is, and what the conditions of his survival are—biology; (3) what has happened to the human race in the past, that is, the large movements—history; (4) by what ideas and organisations the human race lives—anthropology, psychology and sociology; (5) the ideas concerning what it is all about (the basis of values)—religions and philosophy; (6) human achievements in literature, music, and the plastic arts.

These he claims as the basis for humanities; but humanities so interpreted would remove thc need for separate faculties of science. I think that there is still a need for both faculties, but that they should have this basis in common and differ only by the emphasis they give to different parts of it.

If, then, we can accept such a programme as a basis for university education, how in practice will it be possible to fit it into existing overloaded curricula? I feel that the demand to solve this problem, just because of its difficulty, may force its own solution. We cannot teach scientific humanism unless we are prepared to cut down drastically the amount taught in practically every field of teaching. The demand for an extra subject may be the straw that breaks the camel's back. In one academic field after another complaints have been growing more and more insistent for far too many years that most of what is taught, in science and arts faculties alike, is out-of-date, superfluous and generally futile. We continue to teach it ou of that scholastic inertia, fortified by the examination system, which is now probably a worse drag, in a world of rapidly

[1] *Political Quarterly*, xv, No. 4, 1944. This is in turn based on the brilliant though somewhat perverse essay of Ortega y Gasset published as "Mission of the University." Kegan Paul, 1946.

advancing culture, than at any previous period in educational history. Because the curriculum is overloaded, because the teachers are too few and the classes too large, no one has time to think of what he is teaching, and consequently we all go on teaching the same things over and over again. Is it not time to stop and definitely to reconsider and revolutionise rather than merely to revise the whole field of studies? We have to break the old and vicious custom, practised in science and humanities alike, by which new knowledge of recent discoveries in science, or recent additions to literature or the arts, are tacked on at the end of an old curriculum, which is then squeezed so that some of the older and more useless bits gradually decay and fall off.

In science at least we can see now that our presentation of whole subjects, such as physics, could be enormously simplified and shortened by thinking out, in the light of the most recent knowledge of relativity and quantum theory, how to present the older and apparently simpler parts of physics. Already abroad, notably in France and Holland, this has been done. There is no longer any division into heat, light and sound, electricity and magnetism; but the general principles of moving and vibrating systems are taught and illustrated by appropriate examples from optics, electronics and mechanics. In chemistry the situation needs even more drastic modifications. The old chemistry was largely a matter of memory, a set of cookery recipes that had, for no apparent reason but to worry the student, to be learnt by heart. The new chemistry, based on the atomic theory, is, on the other hand, logical, and makes no such demand on the memory. In the biological subjects we are still plagued by the existence of branches of the subject, such as zoology, botany or physiology, that have no logical reason to exist in the light of our present much more generalised knowledge of common biological functions. If we can find the men and money to work out new syllabuses in the natural sciences we could probably get a much better picture of the world of nature with far less call on the memory and far more stimulation to imagination and interest, without losing a bit of the practical capacity which it is still the aim of professional scientific education to achieve.

I have no such knowledge of the changes that would be necessary in the humanities, but it appears from statements

made by humanists themselves that the situation there is not so different. There is much taught for which the only reason is that it was taught before, and the divisions between the subjects themselves are also justifiable more on historic than on present-day grounds. In both cases the trouble is that it has been nobody's business to look into the curricula in a serious and purposeful way. Teachers are too busy teaching; university organisation is too rigid; the examination systems make too many demands. All that is achieved are piecemeal changes in curricula which generally leave them heavier and more complex than before. What we need are appointed whole-time university commissions to revise the curricula, not according to their opinions but according to careful operational research both on the justifications of the existing curricula and the effects of the teaching in the subsequent work and life of the students.

Essentially, what we are aiming at in both arts and science is to reduce the amount of learning in order to be able to increase the range and depth of understanding. To the science courses, so cut down, we would want to add enough of the humanities, particularly history and philosophy, to understand the importance and significance of science in human culture; to the arts courses, a corresponding amount of basic science. At first this would be very difficult to do. The absolute gap of ignorance between these fields of learning is so great that there are very few competent either to teach humanities to science students or science to arts students.

Nevertheless the effort is worth making, and will, I am sure, in the end succeed. But it must be accompanied by a more complete interpenetration of subjects. If a scientific student, for instance, could be assumed to know the outlines of cultural history, the whole of his science courses could be interspersed with detailed allusions to the historical origins and consequences of every scientific discovery about which he learns. How far analogous scientific allusions in the arts would be effective I am not so certain. Here the picture is not symmetrical. In many fields of the creative arts, the historic cultural level has not yet reached into the period of the industrial revolution, and therefore the impact of science is not really felt. But at any rate in works produced in the last twenty years this has ceased to be so, and it is, after all, in the consideration of

contemporary culture that it is most necessary to stress the unity of our culture.

These methods, taken together, will still only begin the process of unification. To be effective they need to be supplemented by a more active and personal collaboration. The experience of the war has taught us, in the widest field of science, the enormous value of the small mixed research team; one composed, say, of a physicist, a biologist, a psychologist and an economist. These men, working together on a common problem, were able to understand each other's approach and methods in a way that no former teaching could approach, and the concentration on the achievement of an object gave a concreteness which fixed this understanding in a way that no purely academic exercise could do. Now what was achieved in practical operational research in the field of science in war might be achieved equally well in the still wider field by analogous methods in peace. We must strive to find concrete projects on which staff and students of different faculties can work together. Such problems have already been furnished by the work of the regional surveys which were carried out in many British cities both before and during the war. The problems of reconstruction after the war offer even more opportunities for similar projects. The question of housing, for instance, is one which involves every single subject that is included in both faculties, from theology to chemistry. Houses are not only made of bricks and mortar, they are part of the tradition of British history; they do not stand by themselves, but as units in the social complex of the neighbourhood; and the reactions of their inhabitants provide a fascinating field for applied psychology. Why can we not find room in our curricula for the undertaking by staff and students together of such general projects? It is there, in examining and studying real practical difficulties, that the varied human and scientific disciplines could become effectively mixed. It is there that the student could receive a foretaste of the experience which he is bound to receive when he goes out into a world of even more complex and interrelated problems.

The fusion between the arts and sciences is, I hope to have shown, both desirable and possible. In conclusion, I would like to emphasise that it is also a vital necessity. It has seemed to many in the last few years a sad paradox that while man's

powers of understanding have everywhere increased, we should find ourselves in a state of want, dissatisfaction and justified apprehension which has not been felt, at least by the upper classes of society, for over a hundred years. To shallow minds which can only see one thing at a time, science is made to be the single cause of our troubles, and it is asserted that man's moral nature is not competent to deal with the vast powers which his intellect has put at his command. They foresee doom, and demand, without either considering it or really expecting it to happen, that we abandon our knowledge and relapse into a pious and mystical ignorance. The alternative to this attitude comes from the realisation that we are at this present moment of time at a particularly critical stage of a transformation that began some hundred years back and may go on for some scores of years into the future.

The characteristic of this transformation is not the existence of machines or atom bombs, or even of science itself. Partly as the result of these developments, but more fundamentally because of the economic and social processes that are largely responsible for them, we are moving towards an era where conscious co-ordinated human activity on a world-scale will take the place of the unconscious and unplanned interaction of separate human wills and desires. Just as for the individual, so for society, ignorance and irresponsibility go together. If we do not know, if we cannot know, the consequences of our actions, we cannot be held responsible for them. But that ignorance must be, in the theological sense, invincible ignorance. It is no excuse to pretend not to know once the knowledge is there and all we have to do is to find it out. In the Soviet Union for nearly thirty years, and in this country during the years of the wars, we know what it means to have a whole society run by conscious and democratic co-operation for a clear and common end. That knowledge carries with it an immense responsibility—a responsibility on every member of the society not only for his own behaviour, but, in so far as lies in his power, for the conduct of the whole society.

It is not surprising that many would wish to shirk this responsibility, to pass it off on to the shoulders of Divine Providence or iron laws. But if we do not shirk it we must learn to understand what it implies. The negative implications are clear enough—the placing of private before public interest is

a waste and a nuisance, and may become a crime. But the positive implications are both more important and more difficult to achieve. To be a citizen in the new world, merely to do one's duty is not enough. The conscious world cannot be made to work either by set rules or by orders from above. Our opposition to the totalitarian state or to the "Fuehrer princip" is not only that it is a diminution of human capacity merely to obey orders, but, more seriously, because a population that merely obeys orders puts demands on those that have to give the orders which no actual or conceivable human being could adequately fulfil. The disaster of Nazism was not caused by the fact that Hitler was mad, but by the very position he occupied and by the philosophy of the state that he so absolutely ruled. The new responsibility of the citizen is to understand his place in the world and to act with others in the light of that understanding. Now the understanding need not be a very great one. It must adapt itself to the capacities of every one of us. But great or small, it needs to be balanced. It needs to include the basis of practical and material as well as social and emotional knowledge and appreciation. Some may have more of one, some of the other. But all must have enough of both to be able to understand each other's language and collaborate in the same tasks. It is for that reason that the union of science and the humanities is for us a condition of survival.

Lecture, Birkbeck College (*Universities Quarterly*, May 1947)

COMENIUS' VISIT TO ENGLAND, AND THE RISE OF SCIENTIFIC SOCIETIES IN THE SEVENTEENTH CENTURY[1]

"IT is inglorious to despair of progress." This quotation from Johann Valentin Andreae[2] was chosen by Comenius to head his preface to the *Great Didactic*. Comenius himself throughout his life never lost his faith in human progress and never ceased

[1] This essay was undertaken in part-collaboration with Dr. Joseph Needham, to whom I am indebted for much of the material.

[2] Like Sir Thomas More, Andreae wrote a Utopia, *Christianopolis* (1619). It is described in L. Mumford's *Story of Utopias* (1923) and there is an English translation by F. E. Held (1916).

from contributing to it. The place of Comenius in the development of world culture is significant. He stands midway between the ordered but mystical world of the Middle Ages and the turbulent and practical world of modern science and industry. He carried in himself the highest ideals of both. It is only in these days that we can begin to appreciate the character of the man who did so much to herald the new age. For at least in its miseries and injustices the world of today is very like that of the Thirty Years' War, which dominated the central part of Comenius' life. He was, like so many of his distinguished compatriots today, a refugee, always sincerely attached to his native Moravia, always hoping to return there, and yet acquiring in his many travels a far wider loyalty to human beings in all countries and climates. What strikes the reader of Comenius almost more than anything else is the comprehensiveness of his outlook and the broadness of his sympathies.[1] This is even more surprising when we consider that his age was one of harsh and embittered controversies in the fields of religion, learning and politics; an age of religious persecution, of civil war, and of the conflict between the new awakening science and the philosophy of the ancients. Comenius was not ignorant of these struggles but he refused to be bound by them. He took his own part but it was the part of humanity and not of sect.

The struggles of the seventeenth century, grim though they were, carried with them an atmosphere of hope and progress, which we see again today. As the battle moved from country to country, the centre of hope moved with it. Driven from the Czech lands and then from Poland, battered by the advance of the Counter-Reformation, the hopes of the pioneers of the new culture centred on Holland, England and Sweden. Comenius was to pass much of his latter days in these countries. In the first half of the seventeenth century, England was probably closer to Continental thought than she has ever been since. The close commercial relations with Holland, the wanderings of political and religious refugees from the Continent to England and back again, the common interests in rising trade and manufacture, led to a community of feeling and knowledge. The intellectual basis for the political and economic revolution that was to give England the leadership

[1] See Note A, page 168.

of the new world was laid by Continental refugees to England such as Hartlib and Haak, and by English refugees, traders and students abroad, such as Digby, Durie and Harvey. Already, in the thirties of the century, England was seething with a ferment of political and cultural ideas which were to lead to the great revolution and the civil wars. The new rising and active populaces of the great cities was more receptive to ideas and more anxious to put them into practice than it was to be for many years afterwards. The time of Comenius' visit was, therefore, opportune, but it had been too long delayed. In 1641 words and ideas were beginning to give way to arms and deeds. In English history, Comenius' visit lies obscured by the events which were immediately to follow it. Nevertheless we can now see how important it was, and though it did not achieve either then or afterwards its professed aims, it had a profound influence on the developments of institutions, of education and of science.

Comenius came to England by invitation. This implies that what he had to give was already consciously desired by leading minds of the country, and indeed all of Comenius' principles fitted with the needs of the time. Where he excelled was in having in his own person the knowledge and experience that existed elsewhere scattered in many minds; and in having a burning faith in the practicability of what he propounded. In essence Comenius' mission was a religious one. He was perhaps the best exponent of the ideals of the Czech Brethren of the Unity, but where he excelled them was in his fervent desire to spread Christianity to a circle far wider than that of the elect, and in his practical conceptions of how this could be done. For him, toleration, peace and justice were far more necessary elements of true religion than exhortation or force; education was the means by which it should be spread. It was in studying education and practising it in the schools that Comenius came to make his greatest contribution, the discovery that education must proceed from an understanding of the needs and interest of pupils and that it must be based on the experience of life which children actually have. But that discovery led him further. In his epoch-making text-book *Janua Linguarum*[1] he attempted to give a balanced picture of the whole of human knowledge and practice. It was the first, and in point of com-

[1] See Note B, page 169.

prehensiveness and simplicity, the best, of modern encyclopaedias, and it gave him the idea of the need to acquire knowledge from things and not from books.

In his great satirical work, the *Labyrinth*, he exposes, as Swift was to do after him, the follies and emptiness of existing learning, and yet he hoped that, by a reformation of that learning and by attention to practical human needs, these follies would be replaced by a true light. In this he was strongly influenced by Bacon, and though coming after Bacon, he really represented, far more than Bacon did, the link between mediaeval and modern knowledge. He had a much stronger feeling than Bacon or the men of the Renaissance for community and for religion, and his sense of social justice enabled him to see the dangers of the pursuit of knowledge for individual enrichment. His own picture of knowledge, as given in his *Physics*, was still essentially mediaeval, but it contained in itself seeds of escape from the net of words by the constant appeal to things. This appeal, he insisted throughout, needs to be made in an organised way. It was thus that he became the prophet and pioneer of the organisation of scientific research. His own knowledge, expressed in his pansophic schemes, was of less importance to history than his insistence on the comprehensiveness and unity of all theory and practice.

Comenius, like Harvey, is a transitional figure between mediaeval Aristotelianism and modern science. Though much of what he says is archaic, he attacks Aristotelian logic like any Glanvill again and again in books such as the *Patterne of Universall Knowledge* (1651), the *Natural Philosophy Reformed* (1651) and even in the *Reformation of Schooles* (1642). His description of the "pansophicall method" in the first of these has a strangely modern ring. It implies in nature, he says, a "perpetual Coherence, a perpetual Gradation, and a perpetual Uniformity." There should be one system of knowledge, one method of study, and "things are so conjoyn'd with things, as alwaies and everywhere the latter may seem of their own accord to arise out of the former." This point of view embodied an appreciation of the coherent quality of established scientific truth, as well as an understanding of natural development and transitions which even the nineteenth century hardly achieved. Or again, the following passage from the *Reformation of Schooles* illustrates how he criticised the application of formal logic to

nature, his criticism being correct though his examples were quaint or even wrong:

> For example, that Metaphysicall Theoreme, *Substantia non recepit magis et minus*, is neither true, nor if it be true is it of any use. For he that is fully growne up is more a man than an em bryo is or an infant in the womb; an Eagle is more a bird than a Bat, and the Sunne is more light than the Moone.

And Comenius appreciated, too, the value of the quantitative approach to natural phenomena. In the *Patterne* he says:

> Truth is a solid thing; the more it is poysed and brandish'd the more purely it shines; nor is there any roome for Impostures, when all places are full of numbers, measures, ballances, and touchstones, nor aught admitted but what hath undergone severe and full examination.

Comenius' appreciation of the role of science in society comes out particularly clearly in his *Via Lucis*, which, though partly written during his stay in London in 1651, did not appear till 1668 at Amsterdam. By that time the Royal Society had been fully constituted, and Comenius dedicated his book to "the torchbearers of this enlightened age, members of the Royal Society of London, now bringing real philosophy to a happy birth." While congratulating them on their efforts, he urged them not to neglect metaphysics and the general enlightenment of mankind.

> Let us then assume [he said] that you, indefatigable investigators of Nature, have conquered her whole domain, so that with Solomon you understand the constitution of the world; the power of the elements; the beginning, the end, the intervening spaces of time; the changes of the solstices, the succession of the seasons; the circuit of the year and the positions of the stars; the natures of living things and the tempers of beasts; the powers of spirits and the thoughts of men; the various kinds of plants and the properties of roots; everything, in effect, that is either plain or obscure—let us assume all this, and then you must know that you have at last mastered but the alphabet of divine wisdom, but reached the threshold in the temple of God; and that his courts and secret places are only now upon your horizon. . . . We adjure you, then, who are priests in the realm of Nature, to press on your labours with all vigour; see to it that mankind is not for ever mocked by a philosophy empty, superficial, false, uselessly subtle. . . . We must say at once and plainly that the main political theories on which the present rulers of the world support themselves are treacherous quagmires, and the real causes of the generally tottering and indeed collapsing conditions of the

world. It is for you to show that errors are no more to be tolerated, even though they have the authority of long tradition . . .; you must show, not only to theologians, but also to politicians, that everything must be called back to Light and Truth.

Significantly enough, Comenius' optimism about the coming enlightenment of mankind was based on what we should today call an evolutionary outlook. The *Via Lucis* contains many fine passages describing the ascent of man from primitive savagery through the beginnings of the arts, to the classical period and so on to the writer's own time. This clear conception of social evolution was much to Comenius' credit, especially in view of the fact that the seventeenth century did not have and could not have had the backing and support which a knowledge of biological evolution gives it in our time. Lack of such knowledge was undoubtedly a limitation to Comenius' thought. It probably goes some way towards explaining his weakness for more or less bona fide chiliastic prophecies such as those of Kotter, Poniatowska and Drabič, which caused him so much unhappiness in his lifetime and about which some of his modern biographers, such as Keatinge, have made merry. Comenius was, in fact, not very sure about his time-scale. But if millenniarism was one of his doctrines, it only made him the more orthodox by the standards of the early Church, and millenniarism has a natural affinity with an ethic and a politic based on social and biological evolution. The *Via Lucis* is full of Isaiah-like prophetic writing about the coming illumination of humanity and its settlement in a state of world peace.

The last part of the *Via Lucis* is devoted to a detailed description of Comenius' practical proposals. "For the Universal Light," he said, "there are four requisites: Universal Books, Universal Schools, a Universal College, and a Universal Language." H. G. Wells's *Outline of History* is the kind of thing suggested by Comenius for his *Panhistoria*, and he would have recognised the partial achievement of his aim in all the inexpensive books of popular education of our day. His universal schools are not yet a reality throughout the world, but the conquest of illiteracy after the 1917 revolution in Russia would have appealed to his spacious mind. And in spite of his attachment to Latin, the Basic English and Esperanto movements would have been hailed by him as a great step in the right direction.

The object of Durie and Hartlib in inviting Comenius to

England was primarily to use his already great influence to persuade Parliament to set up a pansophic or universal college in England and to make England the centre of the great restoration and improvement of knowledge and practice that they foresaw. Other sponsors had in view the more immediate practical question of the reform of elementary schooling. To Comenius both of these were integral parts of his general scheme. The pansophic college as a project was never anywhere realised; it combined in itself too many diverse elements. It was to be monastery, workshop and school in one. In the seventeenth century the learned man was, for all his good intentions, too far removed from practical life to lead the way to such a transformation of arts and technics. It is probable that even if the promoters of the pansophic college had succeeded in creating such an institution, it would have remained a sterile anachronism. It is only now, with our far greater understanding of the relations of knowledge to practice, that any comprehensive organisation of science can fruitfully be attempted.

Nevertheless Comenius' visit did have fruitful results. It is not possible to trace any direct connection between that visit and the foundation of the most vigorous and important of seventeenth-century scientific societies, the Invisible College or Royal Society; in any case it would be unprofitable to do so.[1] The influence of Comenius was in the direction of its foundation. Many of its promoters had met Comenius on his visit to England and were acquainted with his writings. One of the greatest of the original founders, Robert Boyle, was a man with a temperament and motives not unlike those of Comenius himself. The revelation of the knowledge and wisdom of God and the propagation of the Gospel to the heathen were alike the leading motives of the great educator and the great scientist.

To us, still confused by the nineteenth-century conflicts between religion and science, it is difficult to see the extremely close relation which existed in the seventeenth century between mystical, "experimental" Christianity, hard practical self-help and experimental science. Yet a study of the personalities of the seventeenth-century scientists shows all these elements present, and indeed the combination is the keynote of Puritanism—in the conversions of men like Boyle, Pascal and Steno,

[1] The error of this remark has been very justly criticised by Miss R. H. Syfret in *Notes and Records of the Royal Society*, v, No. 2.

and in the poetry of Milton and Marvell. The two roots of modern science, the study of Nature and of human trades, both appeared as eminently religious objects to the Puritan, the first because it would reveal the glory and wisdom of Divine Providence, the second because it could only lead to an increase of sobriety and godly industry. But the religion of the early scientists was not to be united in an organised way, as Comenius would have wished it, with their science. It was, in fact, by a wise necessity that in the scientific societies of the seventeenth century, religion and metaphysical philosophy were alike excluded. The later phases of the Commonwealth in England disabused men of any hope in the rule of saints.

Restoration England was too cynical and worldly to accept the full implication of Comenius' ideas, but it did accept enough of them to make possible the material side of the progress which he so earnestly desired. But in the twentieth century we have lived to see how vain that material progress is without peace and social justice, and how science must be organised for human welfare and not for destruction. The message of Comenius was important in the building up of modern science, but it still needs to be heard to prevent that science from destroying more than it has built.

Note A.—Comenius' awareness of the social injustices of his time is well shown in the following bitter passages from the *Labyrinth*. They occur when human wrongs are being righted at the court of the Queen of Worldly Wisdom:

Now the poor of all ranks came forth with a supplication, in which they complained of the great inequality in the world, and that others had abundance while they suffered want. They begged that this might in some fashion be righted. After the matter had been weighed, it was decreed that the poor should be told in answer that H.R.M. wished indeed that all should have as much comfort as they could themselves desire, but that the glory of the kingdom demanded that the light of some should shine above that of others. Therefore, in accordance with the order established in the world, it could not be otherwise than that as Fortuna had her castle, so also should Industria have her workshops full of people. But this was granted them, that each one who was not idle might raise himself from poverty by whatever means he could or knew. (Sec. 9, "The Humble Supplications of the Poor," p. 255.)

Not long afterwards envoys of the subjects, tradesmen, and peasants came forward, and complained that those who were over

them wished nothing but to drink their sweat; for they ordered them to be so driven and harassed that bloody sweat ran down them. And those whom the lords employed for such purposes were all the more cruel to them, that they also might obtain a small dish at their expense. And as a proof of this they incontinently showed countless weals, stripes, scars, and wounds; and they asked for mercy. And it appeared evident that this was an injustice, and therefore should be stopped; but as the rulers had been permitted to govern by means of these servants, it appeared that they were the guilty ones; they were therefore summoned to appear. Summonses were therefore sent out to all the royal, princely, and lordly councillors, regents, officials, stewards, collectors, writers, judges, and so forth, informing them that they must appear without fail. They obeyed the order, but against one accusation they brought forward ten. They complained of the laziness of the peasants, their disobedience, insubordination, conceit, their mischievous ways as soon as their bit was even slightly loosened, and other things. After these men had been heard, the whole matter was again considered by the council. Then the subjects were told that, as they either did not love and value the favour of their superiors, or were unable to obtain it, they must become used to their ferocity; for thus must it be in the world, that some rule and others serve. Yet it was granted them, that if by willingness, compliance, and true attachment to their superiors and rulers they could gain their favour, they should be allowed to enjoy it. (Sec. 13, "Supplications of the Subjects (i.e. serfs), p. 258.)

Note B. It is interesting to observe the distribution of interest which Comenius uses in the *Janua Linguarum*; thus of the 98 sections of the body of the work, 30 are devoted to natural history, 16 to arts and trades, 20 to learning and culture, 5 to social life, 10 to ethics, 11 to politics, and 6 to religion. It would be interesting to see what the distribution would be in any contemporary attempt to give a comprehensive view of modern knowledge.

From *The Teacher of the Nations* (Cambridge University Press, 1942)

SHAW THE SCIENTIST

All problems are finally scientific problems
(Preface to *The Doctor's Dilemma, Collected Prefaces*, p. 275)

WE are all of us Shaw's pupils, no less the scientist than the playwright and the politician. The present and the past generation, and many generations to come, we hope, have been and will be shaken out of complacency and accepted

ideas by Shaw's violent common sense. In his person he has been the most expressive exponent of the revolt from the pretences of the Victorian era. But in being so he has become so much part of the intelligent background of our own time that it is difficult to write about him without the stupid reverence that he has taught us to make fun of. We cannot see Shaw's thought properly because it is already part of our own.

Now Shaw to the scientist may be two very different things: one easy and one very difficult to recognise. Shaw has often written about science, has made science the central theme of his most important plays and prefaces. In them he writes as a violent and reckless supporter of scientific lost causes, like Lamarckian evolution, and as the enemy both to the theory and practice of disciplines that in the course of years have proved their truth and usefulness, like the bacterial theory of disease. It would be easy to fall into the idea that this puts Shaw among the anti-scientific minority of cranks and mystics, but it would be very wrong to do so. For there is another very different and far more important side which appears, not just here or there, but in almost every word that Shaw has written: a natural, almost effortless grasp of the common-sense scepticism which is the lifeblood of scientific advance: a refusal to have pompous platitudes put over him under any form or backed by any authority: a determination to accept only what seems to him simple, straightforward and fundamentally right.

Explicitly Shaw may stand out against current science: implicitly he understands it. That is why scientists are apt to count Shaw, quite as much as Wells, as one of their own for all the abuse he has hurled at them and for all the contempt in which he holds many of their most sacred theories. For Shaw himself is more than his theories: he is the living proof of them. He is the only man of his age who has maintained a continual and active contact with the changing forces of one of the most chaotic periods in human history. He is the only man who has dared to make predictions and has not seen events give them the lie. We short-livers are no match for him. We may say we understand the present better but we cannot understand its continuity with the past so well. Even to understand Shaw we would have to have his age and his wisdom, for the understanding is that of one integral man. Forty years ago he made his hero, Jack Tanner, say:

I am no more that schoolboy now than I am the dotard of ninety I shall grow into if I live long enough.

(*Man and Superman*, Act I)

Nor is he his foil, Roebuck Ramsden, who at a much more modest age claims to be (Act 1) as advanced as he ever was. Shaw does grow, but he is all of a piece.

The clue to Shaw is this integral personality. His religion, his science, his politics, his way of life were all fitted together into a consistent whole. The paradoxes and the contradictions for which he earned his early reputation were in part a trick of the trade of making people interested in things that really mattered to them, and in part covered his own successful struggle to achieve that integral outlook. We cannot understand the science of Shaw without understanding the whole man. So to unravel the guiding motifs of his thought we have to go back into a past that he has not forgotten but that is one we never knew.

Now science has been a major factor in Shaw's life from the very beginning. He remembers, incredible as it seems to us, the pre-Darwinian era where as a small boy he heard an elderly man ask for

the works of the celebrated Buffoon. My own works were at that time unwritten or it is possible that the shop assistant might have so far misunderstood him as to produce a copy of *Man and Superman* . . . the celebrated Buffoon was not a humorist but the famous naturalist, Buffon. Every literate child at that time knew Buffon's *Natural History* as well as Aesop's *Fables*. And no living child had heard the name that has since obliterated Buffon's in the popular consciousness: the name of Darwin. Ten years elapsed. The celebrated Buffoon was forgotten; I had doubled my years and my length; and I had discarded the religion of my forefathers.

(Preface to *Back to Methuselah, Collected Prefaces*, p. 501)

The advent of Darwinism and the controversy that raged round it were a terrific formative influence, the importance of which it is difficult for us who have not felt it to imagine. Shaw reacted against Darwin violently. That reaction was not an anti-scientific one but neither was it scientific. What Shaw objected to in Darwinism was derived in part from its political and social implications and in part from his deep-seated and strongly held feeling of the community of society and the

wider community of living things which had become for him the equivalent of the religion he had discarded.

There was another current in the late nineteenth century which also drew him in. The twin star to Darwin in the scientific heaven of the seventies was Pasteur. With Pasteur and his followers, the vivisectionists and the vaccinationists, Shaw fought an unending and futile battle; futile, on one side, because doctors continued their useless and inhuman ministrations and, on the other, because he himself continued to live hale and hearty without them.

These two—the Darwinian controversy and the germ controversy—were Shaw's most passionate scientific concerns but they were not the only ones. It must not be forgotten that Shaw had been a professional scientist though for an even shorter time than he had been a successful man of business, and his first hero, indeed, was not a biological but a physical scientist (Edward Connoly, *The Irrational Knot*). He was one of the new kind of practical scientists, the electrical engineer. He was created from Shaw's own experience in the Edison Company's office during the first installation of the telephone system in London in 1880.

> As I was interested in physics and had read Tyndall and Helmholtz, besides having learnt something in Ireland through a friendship with one of Mr. Graham Bell's cousins who was also a chemist and a physicist, I was, I believe, the only person in the entire establishment who knew the current scientific explanation of telephony; and as I soon struck up a friendship with our official lecturer, a Colchester man whose strong point was pre-scientific agriculture, I often discharged his duties for him in a manner which, I am persuaded, laid the foundation of Mr. Edison's London reputation.
>
> (Preface to *The Irrational Knot*, *Collected Prefaces*, pp. 682–3)

In *In Good King Charles' Golden Days* he shows that he has still kept alive his interest in the great physical controversies of the age of relativity. But Shaw's interest in physical science for one very obvious reason never played a dominating part; he could never, in spite of his association with the Webbs, take a deep interest in figures. On his own admission

> Mathematics are to me only a concept. I never used a logarithm in my life and could not undertake to extract the square root of four without misgivings.
>
> (Preface to *The Doctor's Dilemma*, *Collected Prefaces*, p. 269)

Yet in spite of this he was able to appreciate the importance of what he could not understand, and by his championship of Karl Pearson showed he was a prophet of the new methods of statistical analysis that have proved the major means of extension of exact science into the fields of biology and sociology.

The most characteristic scientific aberration of Shaw's was his violent reaction to the natural selection of Darwin in favour of the creative evolution derived from Lamarck. The whole of this he has argued out with admirable lucidity and wrong-headedness in the preface to *Back to Methuselah.* Here he shows himself a violent follower of that neglected genius of the late Victorian age, Samuel Butler. This preface is a document which should form part of every biological student's education because it shows better than any other single piece of writing both the social origins and the social effects of Darwin's teaching. Shaw is not fooled for a moment about the scientific objectivity of Darwin. He realises that Darwin has introduced into biology what *laissez-faire* economics had released in public life—unlimited competition. He shows also why Darwinism was hailed as a doctrine which delivered men from the intolerable mental agony of a theology based on a personal god who, it seemed, in the light of the manifest evil in the world, must be either himself wicked or impotent.

> We had been so oppressed by the notion that everything that happened in the world was the arbitrary personal act of an arbitrary personal god of dangerously jealous and cruel personal character . . . that we jumped at Darwin.
>
> (Preface to *Back to Methuselah, Collected Prefaces,* p. 520)

But, as he immediately points out, the gulf that swallowed up Paley and Shelley's Almighty Fiend was nothing less than a bottomless pit in which there was

> a hideous fatalism, a ghastly and damnable reduction of beauty and intelligence, of strength and purpose, of honour and aspiration, to such casually picturesque changes as an avalanche may make in a mountain landscape, or a railway accident in a human figure. . . . If it be no blasphemy, but a truth of science, then the stars of heaven, the showers and dew, the winter and summer, the fire and heat, the mountains and hills, may no longer be called to exalt the Lord with us by praise: their work is to modify all things by blindly starving and murdering everything that is not lucky enough to survive in the universal struggle for hogwash.
>
> (Preface to *Back to Methuselah, Collected Prefaces,* p. 520)

This passage is a clear and eloquent expression of an emotional reaction to the Darwinian theory rather than an intelligent criticism of it. Shaw recognises this perfectly well. He admitted that Darwinism was not finally refutable, though not as an explanation of evolution as a whole but only as an explanation of certain small and trivial parts of it.

In its place he accepted as an infinitely more satisfying solution, equally impossible to disprove, the theory of Lamarck of functional adaptation later called creative evolution. The basis for this preference, apart from its echo of a mediaeval intelligible world order which Shaw had taken in with his cultural inheritance, was a deep immediate sense of the unity and purpose of all created things. Shaw felt in control of himself: he felt a kinship with other living things, and he felt therefore that they could control their own existence and their own evolution. If they did not want to evolve they would not, and if they did want to evolve they would. He had an avowed affinity to the mystical naturalist of the type of Oken, who believed that natural science was "the science of the everlasting transmutations of the Holy Ghost and the world." (For some reason Shaw seems to have thought of Oken as a philosopher rather than the very serious and practical anatomist that he was.) The inner life, the inner drive of evolution—evolution from within—felt much more true to him than an evolution from blind external forces—evolution from without. This led him into a strange physiological theory in which all the functions of a living organism are treated as habits:

> For instance, the very first act of your son when he enters the world as a separate individual is to yell with indignation: that yell which Shakespeare thought the most tragic and piteous of all sounds. In the act of yelling he begins to breathe: another habit, and not even a necessary one, as the object of breathing can be achieved in other ways, as by deep sea fishes. He circulates his blood by pumping it with his heart. He demands a meal and proceeds at once to perform the most elaborate chemical operations on the food he swallows. He manufactures teeth; then discards them; and replaces them with fresh ones. Compared to his habitual feats, walking standing upright and bicycling are the merest trifles; yet it is only by going through the wanting, trying process that he can stand, walk or cycle, whereas in the other and far more difficult and complex habits he not only does not consciously want nor consciously try, but actually consciously objects very strongly.
>
> (Preface to *Back to Methuselah*, *Collected Prefaces*, p. 509)

Because things once striven for and learnt can become habits, Shaw argues that things which are now habits must have been at one time striven for. He recognises, quite rightly, that there is a serious problem for zoology in explaining the things that happen of themselves. He senses an earlier history to account for these things but he is unable to conceive of their history as other than the operation of a conscious will pervading the whole of nature. Shaw never seemed to see that there is any difference between the conscious and unconscious parts of living matter. He even attacks the Darwinians for denying consciousness to trees.

Now all this would tend to make the modern hard-boiled scientist say, "We have no patience with feelings or with attitudes towards life that cannot be translated into experiments leading to predictable results." But it would be a mistake to think that is what Shaw is after. What he looked for and what he found was a religion by which to live a most effective and fruitful life: and religion, in his sense, purged from the old social heritage of oppressive tyrant gods, is not one to be despised. If Shaw had been a scientist—and there have been many scientists who have talked far greater nonsense than he has—he could reasonably have been attacked as not distinguishing between what he wanted to believe and what he had any evidence for believing. But he was not a scientist and he made what was in his time a most penetrating and intelligent choice of beliefs.

Shaw's attitude towards evolution and his attitude towards medicine are most closely related. They both arise from the common feeling—perhaps the most deeply held of all his convictions—on the substantial unity between men and animals. Shaw never saw the reason why, if an action towards a man were criminal, an action towards an animal should not be as much so; this is the logic behind his consistent vegetarianism and his implacable opposition to experiments on animals in general and to vivisection in particular.

> I am driven to the conclusion that my sense of kinship with animals is greater than most people feel. It amuses me to talk to animals in a sort of jargon I have invented for them; and it seems to me that it amuses them to be talked to, and that they respond to the tone of the conversation though its intellectual content may to some extent escape them. . . . I find it impossible to associate with animals on any other terms.
>
> (Preface to *Killing for Sport*, *Collected Prefaces*, p. 140)

While admitting this feeling Shaw does not elevate it into a dogma, nor does he try to draw impossible conclusions from it as Butler's Erewhonians did when they passed from the refusal to eat meat to the refusal to eat vegetables. He recognises that some animals must be killed and even that some must be eaten but he hopes that this habit will not persist! What he cannot stand are that the sufferings of animals should conduce to the increase of man's pleasure or knowledge; he is as great an enemy of blood sports as he is of vivisection.

Shaw's attack on vivisection in the preface to *The Doctor's Dilemma* is a very fine example of his understanding and its limitations. He begins by granting that the right to know is like the right to live. But, he goes on, the right to live is not unconditional, it must not violate someone else's right to live; nor should, he argues, the right to know. We are not entitled to kill people for the sake of knowledge: the kind of experiments that were later to be carried out in the German concentration-camps were indefensible even if they had—which they did not —contributed to knowledge. Now if man and animals are fellows, the same argument will apply:

> Just as even the stupidest people say, in effect, "If you cannot attain knowledge without burning your mother you must do without knowledge," so the wisest people say, "If you cannot attain knowledge without torturing a dog you must do without knowledge."
>
> (*Collected Prefaces*, p. 255)

Because he feels this so strongly, he goes on to say that, as the wise man does not care to learn from vivisection, there is no excuse for it at all: but still the original problem is not solved —the right to know is not exercised. Shaw has an answer to this as well, that

> There are many paths to knowledge already discovered; and no enlightened man doubts that there are many more waiting to be discovered. Indeed, all paths lead to knowledge; because even the vilest and stupidest action teaches us something about vileness and stupidity, and may accidentally teach us a good deal more.
>
> (*Colleoted Prefaces*, p. 263)

Therefore if certain paths are barred from consideration by humanity, alternatives may be available and the wise man and the man of honour will choose these.

Now there are two answers to this type of argument: the first which attacks the premises that equates human and animal suffering—and I will return to that later—and the second that doubts the conclusion. If all men and all scientists were ideally wise and honourable they might have discovered what they have discovered without recourse to any animal experiments. It is certainly also true that the greater proportion of animal experiments—as the greater proportion of all experiments—prove nothing; but men being what they are, of limited wisdom and limited range of sympathy, it is too much to ask them to find by circuitous ways what they have only wit enough to find by the most direct way. If we had to learn science all over again from the start we could undoubtedly do it in a far more humane way than was actually done; the men of the past, scientist and layman alike, were hard to animals, to other men and to themselves. Now we know better and are able better to appreciate what kind of sufferings are involved in experiments, and to see that suffering is minimised and justified by a manifold decrease in suffering which the knowledge of it brings. This, of course, Shaw would have disputed and will, as far as I know, dispute still. Seeing the triumphs of science expressed in practice by the doctors he may yet with some justification retain his scepticism and his indignation.

Parallel with his condemnation of vivisection goes Shaw's objection to vaccination and, with it, most forms of immunisation. His reasons for this are more difficult to follow because they are not based on such immediately simple responses. It is not at all clear how, in the course of his life, Shaw's attitude towards the work of Pasteur has varied. In 1911 he goes flat out and damns bacteriology as a superstition: the germ, he thinks, may be a symptom of the disease and not its cause. Now of course Shaw had lived in the period of the early enthusiasm and excesses of the germ theory, where scientists as much as doctors took Pasteur's work as divine revelation and thought that all disease was due to germs, could be cured only by killing them, and that killing the germ stone dead was more important than any incidental damage that might be done to the patient. If the germ could not be found, it was probably there anyhow and a vaccine of an unspecified character should be able to do for it. None of these absurdities escaped him, but what does seem to have escaped him was

that through this maze of exaggeration and false theory there ran a progressive thread which has emerged as the years have gone on as a surer and surer guide to the prevention as well as the cure of disease. The path of discovery has not been kind to Shaw: the viruses which were invisible in his day can now be photographed and the beneficent ones—the bacteriophages—seen at work attacking their prey.

Shaw's objections, however, are not based mainly on scientific scepticism, they are of a more positive nature. They seem to owe their vehemence mainly to his objection to the interference with the liberty of the subject rather than to any medical theory. A great deal of Shaw's objections were in his days reasonable, valid ones:

> When, as in the case of smallpox or cowpox, the germ has not yet been detected, what you inoculate is simply undefined matter that has been scraped off an anything but clean calf suffering from the disease in question. You take your choice of the germ being in the scrapings, and, lest you should kill it, you take no precautions against other germs being in it as well. Anything may happen as the result of such an inoculation.
>
> (Preface to *The Doctor's Dilemma*, *Collected Prefaces*, p. 249)

Further, this is the theme of *The Doctor's Dilemma* itself—that such complicated matters as introducing foreign substances into the human body is one that cannot be left either to sixpenny or Harley Street doctors who have not the time, incentive or the basic knowledge to do it properly. In this sense his criticism is fully constructive and points to the need for properly equipped scientific laboratories to take the place of the G.P.'s back surgery.

In *The Doctor's Dilemma* and its magnificent preface Shaw shows to the full his capacity for social understanding of the medical profession exceeding anything that has been written of it before or since. He saw, long before his time, that the chief enemy of health was poverty and not lack of medical attention; and he saw too that in his time medical attention, for lack of science, could do very little for people and was in fact not able to do that little because the poor could not afford the treatment and the rich could not be made to undertake it. The social solution to the medical problem that he put forward is now, forty years later, likely to become the law of the land against the protests of a generation of doctors who are un-

changed replicas of those he so mercilessly satirises. The maxims with which the preface ends ring as true today as they did when they were written nearly forty years ago:

> 1. Nothing is more dangerous than a poor doctor; not even a poor employer or a poor landlord.
> 2. Of all the anti-social vested interests the worst is the vested interests in ill-health.
> 5. Make up your mind how many doctors the community needs to keep it well. Do not register more or less than this number; and let registration constitute the doctor a civil servant with a dignified living wage paid out of public funds.
> 6. Municipalise Harley Street.
> 12. Do not try to live for ever. You will not succeed.
> 13. Use your health, even to the point of wearing it out. That is what it is for. Spend all you have before you die; and do not outlive yourself.
> 14. Take the ustmost care to get well born and well brought up. This means that your mother must have a good doctor. Be careful to go to a good school where there is what they call a school clinic, where your nutrition and teeth and eyesight and other matters of importance to you will be attended to. Be particularly careful to have all this done at the expense of the nation, as otherwise it will not be done at all, the chances being about forty to one against your being able to pay for it directly yourself, even if you know how to set about it. Otherwise you will be what most people are at present: an unsound citizen of an unsound nation, without sense enough to be ashamed or unhappy about it. (*Collected Prefaces*, pp. 280–1)

The major problem for scientists in contemplating Shaw's attitude towards science is how to explain his combination of natural common sense and penetrating judgement with his predilection for backing scientific lost causes and for appearing to fly in the face of the evidence of experiment and observation. The problem has an importance even greater than that of the analysis of the work of a great writer. It is the problem of a whole generation of European thought. Shaw is profoundly concerned with social human betterment in his advocacy of socialism on one hand, and on the other with man's understanding of a changing universe in his belief in creative evolution. He has admitted and succeeded to his own satisfaction in combining these two attitudes, but he has done so in a way which has isolated him—except in general bonds of affection and respect—from active scientific and political movements. This isolation he feels to a very considerable extent himself.

In one of his later prefaces, that of *The Simpleton of the Unexpected Isles*, written only ten years ago, he even appears to turn against science altogether:

> Religion is the mother of scepticism: Science is the mother of credulity. There is nothing that people will not believe nowadays if only it be presented to them as Science, and nothing they will not disbelieve if it be presented to them as religion. I myself began like that; and I am ending by receiving every scientific statement with dour suspicion whilst giving very respectful consideration to the inspirations and revelations of the prophets and poets. For the shift of credulity from religious divination to scientific invention is very often a relapse from comparatively harmless romance to mischievous and even murderous quackery.
>
> (*Collected Prefaces*, p. 636)

If other people want to believe what he cannot believe they are credulous: and if they will believe without evidence, he seems to tend rather to their holding the old than the new beliefs. Now, of course, without the kind of education which we have not even begun to think of in this country, the vast majority of the people must be credulous: that is, they cannot possibly know the reasons for the beliefs they hold. But that does not mean that the reasons are not there. The old beliefs were metaphorical and poetical and expressed a kind of justificatory synthesis of traditional behaviour and traditional social structure. The new, scientific beliefs express explicitly the growing material control of man over nature. If we despair of the latter by a too easy reading of the effects of human folly over the last few centuries, we may be forced to fall back on the former which, unfortunately, however harmless, neither explain nor help us to control the forces that are so torturing the world today.

Now the intellectual reason that drove Shaw to this choice is one deeply rooted in one of his most strongly held beliefs and further impressed on him by a youth lived in the middle of the evolutionary controversy. It is a belief that animal evolution and human society are explainable by the same theories, a belief now becoming to be known as biologism and one still held by many far younger scientists and philosophers. Once biologism is taken for granted the precise mechanism of evolution becomes of vital importance. If a belief in Darwinian natural selection immediately implies a justification of survival of the fittest, cut-throat competition and all the horrors

of individualist capitalism, then Darwinism must go and be hanged to the evidence. Lamarck's far more human concept of evolution, making it dependent on conscious will and therefore making possible of achievement by world action a better state of affairs, is clearly a morally preferable alternative.

Biologism had another attraction for Shaw: his deep, instinctive feeling of an almost personal relation with animals. It was for this reason that he could never accept the older philosophic view finally incorporated in Christianity, that man and animals were different orders of creation, with man alone having a rational and, at least potentially, an immortal soul. Now in their reaction to the older theology, evolutionists of all kinds stressed the immediate kinship between man and animals, that shown in every hair of their bodies, and overlooked the distinction that had been obvious from the earliest ages of civilisation between man and animal's behaviour and social organisation.

Here, strangely enough, Shaw missed or reacted against the impact of a movement which accepted both the facts of evolution, linking man and animals, and the fact of man's social organisation sharply differentiating him from them. Marx and Engels, living in the England of Shaw's youth, did not fail to influence him, but their influence was purely on the political and economic and not on the philosophical side. *Das Kapital* made Shaw a socialist, but for the philosophy of dialectical materialism as exemplified in the other works of Marx, and particularly those of Engels, he has only the most generalised abuse which shows that he either never read it or did not take it in. I hope it will still be possible to hear what Shaw has to say on Engels, because the thesis developed in such a book as *The Origin of the Family* shows how it would have been possible for him, if he accepted it, to reconcile his social beliefs with an entirely non-mystical and practical biology.

The Darwinian theory, after a momentary dimming at the turn of the century, is now more firmly established than ever, as its material basis in the genetic mechanism of Mendel and Morgan has at last been elucidated. We can not only observe the occurrence of new species but we can make them with X-rays. The scientist of today, however, sees evolution much more in wider perspective than those of the nineteenth century. He sees that the establishing of family trees is but a very small

part of the work of the biologist; that by patient experiment and ever more profound observation the actual complex relations between organisms and their living and non-living environments will need to be worked out.

One of the characteristics of the development of science from the fifteenth century up to almost our own time has been taking as literal statements what the ancients had understood figuratively, and proving them to be nonsense. The task of our day is to explain what it was that the ancients were trying to express because the fact that they bothered about it at all showed it to be important. Thus Aristotle and Galen, and after him Aquinas, discussed at length the differences between the vegetative, the animal and the rational soul, and conceived of them as seated in the liver, the heart and the brain. Vesalius and Harvey destroyed this concept as a material description; the liver was a food store, the heart a blood-pump and the brain a complex telephone exchange and record office. But they did not attempt to get behind what the ancients meant by these distinctions; how they had used these words to strive to explain the mere growing and formative power of plants and animals, the behaviour and responses of animals, and the power of abstract reasoning which was possessed by man alone. Now we are beginning to see what these mean; how the vegetative soul is the expression for the totality of all biochemical phenomena which are common to all living things and date back to the very origin of life itself; how the animal soul belongs only to mobile animals and to the few exceptional plants that have accidentally drifted into their mode of life. Sense organs, movement, desire and striving are all included in that pattern of structure and behaviour. Both the vegetative and the animal souls could develop through the mechanism of inheritance and organic evolution. The rational soul is different. The ancients were right. Man stands completely apart from the rest of creation; and, in their time, they were right too in demanding a special act to account for this uniqueness, even if they expressed it in the crude, materialistic sense of a God breathing life into moulded clay. But the ancients and with them the moderns with rare exceptions, up to the present century, missed the relevance of the rational soul. The evolutionists, Darwinian and Lamarckian, were so concerned with proving Garden of Eden fables to be nonsense that they were in danger

of perpetrating a greater nonsense themselves: greater, that is, considering that they ought to have known better. They were so busy in seeing that men were descended from animals that they did not look for the circumstances that had made them so absolutely and qualitatively different from them—the organisation and development of human society. Darwinians and Lamarckians were alike in this. The Darwinians were so certain that animals had no souls they would not allow them to men either and tried to account for the unique position of man by granting him a larger brain. The Lamarckians, equally determined to stress the unity of creation, insisted on giving souls or creative wills to every animal because they observed that man possessed them.

In the choice between the two, Shaw very naturally decided in favour of the more humane though the less intelligible of these alternatives. He was a man of his time in thinking of evolution essentially in terms of physical inheritance and race. His Supermen and Methuselahs are to him as much the product of the evolution of the body as the dog or the oak tree. Because to expect such changes to happen by some accidental gene variation would be palpable nonsense and because Shaw instinctively and consciously felt that such changes were needed, he was prepared to argue through thick and thin against the Darwinian hypothesis, not imagining that though the problem he put before himself was a right and just one, the method of solution through evolution had already been superseded a million years ago when human society first pulled itself together in this world.

Shaw was deeply aware of the vast contradiction that exists between the limited power in space and time of our bodies and the range and time that our minds need. He was aware, in other words, of the discrepancy between the products of organic evolution and the products of social evolution. The whole theme of *Back to Methuselah* is an attempt to resolve this by the simple device of making men achieve an adequate length of life through the inner will-power of creative evolution. I am not sure how far Shaw really meant what he said there: how far it expressed sincere belief or must be taken as an allegory as much the history of the Garden of Eden. But it is clear that, allegory or not, Shaw never attempted the other solution through social rather than organic evolution.

Yet there have been few more profound analysts of our society. Shaw could penetrate its manners, bring out their latent historic and economic roots: could show us as no one has ever done so well the follies and stupidities of our own conventions. By so doing he has changed them. If the world of 1946 is a different world from the world of 1856, it is to a very perceptible extent because of Shaw's own work. More than that; throughout the vast historic changes of these ninety years, Shaw has never lost an instinctive feeling for the direction of significant social change. When others who ought to have known better derided the efforts of the struggling Soviet Union, he supported it. He had no patience with sentimental appeals to mid-Victorian liberalism. He knew it was dead for he helped to kill it. But he did more than destroy. He has given to succeeding generations self-confidence—a capacity to look at the world as something which men could control and improve if people could look at it simply and clear their minds of cant. His beliefs—the new religion he made out of creative evolution—helped him so to see the world and so to change it. If it is not the religion of the generation of today and tomorrow, it is largely because he has made such a thorough job of clearing away the nonsense of the past and given us a field in which we can build a more rational, a more comprehensive and a more hopeful future.

From *G.B.S. 90* (Hutchinson, 1946)

SCIENCE AND THE ARTS

INTRODUCTION

THE three essays in this section deal with more visual aspects of culture: painting, sculpture and architecture. The first two, written before the war, deal essentially with ideas and point out how modern science can influence the arts, both by the interpretation it can give to aesthetic performance and appreciation, and by the new matter it provides for aesthetic treatment. They were the fruit of much discussion with artists and architects and a move towards the bridging of the great gulf which, in the nineteenth century, was cut between the arts and the sciences. In these essays, however, for the most part the connections between the arts and the sciences were conceived of on an almost entirely intellectual plane. If I were writing them now, I would emphasise much more the general social nature of both artistic and scientific creation and the great importance of relating both to popular consciousness and popular participation. The last essay sounds a different note. It was written as a result of a more practical experience of the war and of the more concrete ways in which science can assist architecture in design, in materials and structures, and most of all in the study of the purposes for which buildings are needed. The contrast between the two articles on "Architecture and Science" and "Science in Architecture" may stand as an index for the transformation wrought by the experiences of the war.

ART AND THE SCIENTIST

ONE of the features of the civilisation out of which we are now passing was its rigid separation of human functions into different spheres. Every man tended to have a job, to be a specialist in something. The great branches of human culture

seemed to move further and further apart. In particular, art and science became two entirely separate spheres which did not even touch at any point. The last official link was the annual reviews of the Royal Academy which used to be given in *Nature*, and in which the Academicians were chided for putting the moon the wrong way up in the sky or for painting a flower with too many petals. But even these have now been discontinued, and for the official scientist a picture or statue might just as well not exist.

It had not always been so. In the great creative periods of science the artists and scientists worked very closely together and were in many cases the same people. It was to the interest in the visual arts that we owe the birth of accurate observation of nature. It was the problems of architecture that gave rise to the science of mechanics. Leonardo da Vinci, though the greatest, was only typical of whole schools of artist-scientists.

Gradually, however, with the development of bourgeois culture the useful and the ornamental were piously separated. Science was used to make the money, art simply as a means of spending it. The result of this separation has been the most incredible mutual ignorance. The scientist totally ignores art, the artist works as if science had never existed. Yet, particularly at the present day, both have to learn from one another enormously. The whole modern movement in art did, in fact, originate not only from the revulsion of the artists to the lavish and aimless materialism of nineteenth-century painting and sculpture, but also from a slight inkling that the problems of perspective and natural colouring which they had inherited from the artist-scientists of the Renaissance were not the only problems for the artist and that the more recent developments of science, particularly the new theories of vision, demanded new art to go with them.

In the Impressionists, and particularly Seurat, this tendency was manifest, but the contact there made was not renewed until our own time, and then it was not with science but with technics. Through the Constructivist school and the Functionalist architects, the artist began to see new and more rigid harmonies which the necessities of engineering and economics had imposed on the technician. Even this contact, however, was casual and imperfect. There has been no attempt to think out the full implications of modern science for art, and indeed

it is doubtful if there is anyone yet capable of doing it. What follows are rather notes and suggestions of the lines along which such an analysis might be made.

We can consider the different aspects of art for this purpose as the formal or modal, the content of art, and its direction or intention. One of the earliest and most marked tendencies of the new development in art has been its insistence on its formal character, whether this betrays itself nakedly as a purely formal or abstract art, or implicitly underlying more elaborate and realistic representations.

What is so particularly interesting about this development is, however, that in many ways it represents a recapitulation of the progress of mathematical and physical thought over the period from the Renaissance to the present day. Early art was elementary in its geometry though with intimations of the intricacies of the hypergeometries of the modern mathematicians. The artist has discovered by intuition and practice many of the stages of this geometrical development. Take for example symmetry. Classical art knew only the simplest bilateral symmetry. Modern art, on the other hand, while ostensibly rejecting symmetry altogether is effectively reintroducing it in more complex form. These forms have been known, but outside the classical tradition, particularly in the art of savage races, where the sense of rhythm is far more highly developed. The basic concepts of the three-dimensional symmetry are those of rotation, such as the symmetry of a flower; of inversion, as in the difference between the right hand and the left hand; and the combination of these with each other and with direct movements in space. This can be done only in a limited number of ways: 230 for three dimensions, seventeen for two, but this is only for regular figures. By altering the scale a far larger number of internal harmonies, depending essentially on symmetry, can be introduced. Some of the more abstract artists have produced intuitively many of these complex rhythms. Architecture in particular gives great opportunities for symmetrical rhythms.

The question arises as to whether an actual knowledge of what the artist is doing would add or detract from his own production or our appreciation of it. Only the event can decide, but the analogy of music may here be helpful. In music the relations of tone and rhythm are for physiological and

physical reasons particularly simple. They were realised in practice long before there was any theory, but the advent of theory, far from stifling musical originality, gave it an enormous impetus—the rules of harmony and counterpoint worked as liberating restrictions, and the same might be true in the visual and constructive arts. A picture or a building might be conceived in a certain symmetry combination, much as a musical composition is written in a key.

Another aspect of modern art which recapitulates mathematical forms is the development of line and surface. Here again, classical art was limited to a small number of curves and surfaces: circles, wave forms, spheres and cylinders. Modern art has evolved many more subtle forms, especially sculpture, which now depends on far more complex curves and surfaces. Negative curvature (saddle or hourglass shape) is characteristic of much modern work, such as that of Henry Moore, as are the subtle inflections and the use of nodal points. In the work of Barbara Hepworth there is an extraordinary intuitive grasp of the unity of a surface even extending to surfaces which though separated in space and apparently disconnected yet belong together both to the mathematicians and the sculptor. The stages of this evolution are interesting. Originally surfaces are chosen as presenting the most easily executed representation of a natural surface—the dome of a head, or the curve of a torso. In this nature is always pulling back and tends in the end to destroy the original simplicity in accurate but insignificant detail. By becoming abstract these restrictions are removed and the study of the forms themselves, moved only by subconscious strivings to representation, can be developed. At a later stage the two may come together again in a realism informed by the previous analytic study.

The Cubist school exemplify another attempt at the solution of the problem of surfaces, here resolving them more usually by their principal tangent planes, or occasionally, as in the work of Pevsner, by normal planes, but in either case carrying out an algebraic discontinuous decomposition as a prelude to a more complex and understanding synthesis.

To this purely geometric aspect of form has been added in tradition another more mechanical aspect. Every building, and ultimately every picture, is anthropomorphised in some inner way so that the effort of lifting and supporting its various

parts is instinctively felt on seeing it. The conception of balance and composition in art is a mixture of appreciation of geometrical symmetry and static compensation. To this must be added the quite different dynamic balance which occurs only for movements, the balance of the bicycle-rider or the wheeling bird. How representational art, even in its most abstract form, can suggest this balance and through it the implicit stillness or motion of its parts is still an unexplored field in the psychology of sensation. Here again the artist has been busy solving problems in practice for which the theoretical formulation is yet largely wanted.

The problem of content is a much more serious one for modern art. In the earlier stages of revolt from nineteenth-century art, content was explicitly neglected in favour of form. A certain choice of content was still made but formal objects, and particularly surfaces whose forms gave rise to problems, were specially selected. The human figure remained because of the richness of forms which it could present, and, though not explicitly, because of its traditional psychological implications. Musical instruments, fruit, houses, machinery were all taken up from this point of view. Another way in which the content could be formalised was presented by Constructivism, where what was represented was essentially between forms such as occur in modern engineering practice, but with a strong tendency to geometricisation and abstraction. Finally, in the later developments of purely abstract art the content is reduced to the simplest geometric forms—rectangles, spheres, cylinders and their positive and negative aspect; of which the abstract bas-reliefs of Ben Nicholson, curiously reminiscent of the equally formal stonework of the Tiahuanaco culture, may stand as a fitting example.

Against this tendency two different streams of reaction have grown up, both concerned with the apparent contentual poverty of abstract art. The surrealist movement depends essentially on introducing literary or psychological content into formal compositions, but it is one in which the rules of composition themselves are no longer mathematical but psychologically guided. Surrealism also significantly draws on a field of content new to art, that of biological structure. Although for the most part it uses the cruder, more accessible and consequently more emotive dissections of man or the higher animals,

it does in principle open the field of biological science as a new source of pictorial content.

The other type of reaction is sociological rather than psychological. The earlier stages of the revolution of the arts were essentially occupied in solving certain problems of presentation, but this modern artists are finding increasingly unsatisfactory. Problems have to be solved, but the solving of problems is not enough. The artist no more than the scientist can occupy himself in permanent satisfaction with the contemplative and analytic sides of his work. Socially art is not complete unless it passes from the solution of problems to something of more immediate social utility. It is true that the artist can as citizen, and particularly among other artists, express and carry out political activities. The question, which is one for artists and scientists alike, is: can he do so as artist or scientist? Can the discoveries which have been made in the last thirty years in the field of much more conscious and less tradition-ridden presentation of form be used to produce painting and sculpture which is a powerful part of the social movements of the time? Clearly to do so may involve a return to representation, but it should be a return on a different level of experience.

The artist at the moment is in his work necessarily divorced from organic social expression, simply because in our civilisation there is practically no vehicle for such expression. Paintings and sculptures are purchasable objects, not parts of well-conceived social construction. As long as this remains so, there can be no satisfactory solution, but this does not mean that nothing can be done. Even a civilisation in a state of transition must be able to find expression through its arts for the struggles that are going on. The expression need not, in fact should not, take the obvious and hackneyed forms of revolutionary art. Nor, on the other hand, can it be left to the artists in isolation to discover what form it should take.

Scientists and artists suffer not only from being cut off from one another but being cut off from the most vital part of the life of their times. How to end this isolation and at the same time preserve the integrity of their own work is the main problem of the artist to-day. There are no ready-made solutions, but if the goal can be seen the way to it will be found.

From *Circle* (Faber and Faber, 1937)

ARCHITECTURE AND SCIENCE

OF all the arts, architecture is the one that has, throughout its history, been most closely connected with science. Indeed, the closeness of this connection may be taken as some indication of the state of excellence of architecture at any period. All through classical, Byzantine and mediaeval times the great architects, such as Vitruvius, Anthemius or Villard de Honnecourt, were men who certainly knew, and were able to use, all the science that existed in their time. The construction of mediaeval cathedrals exhibited, in fact, the greatest practical demonstration of the validity of science that the Middle Ages could produce. It was, however, in the Renaissance, a great period both for science and for architecture, that the relation was especially close. To a large extent, modern science itself owes its inception to the interest of the architects. Leonardo da Vinci studied with equal concern the fabric of buildings and of human bodies. The foundation of science in England has amongst its greatest figures two men, Wren and Hooke, of whom the first deserves more credit as a scientist and the second as an architect than they are usually accorded.

It was only after the seventeenth century, when both science and architecture became professionalised, that this close personal contact disappeared. It maintained itself through the eighteenth and early nineteenth centuries only in the tradition of the great civil engineers, in the builders of bridges, railway stations and factories. The academic architect and the academic scientist were poles apart. The result has been unhappy for both sides. The essential superficiality which marked the decay of architecture in the nineteenth century and still marks school architecture today is due to a preoccupation with appearance rather than structure or function. On the other hand, the scientist had not been forced to consider such problems as the nature of materials and their combination that an organic link with architecture would have provided. The gothic Cavendish Laboratory at Cambridge and the science museums at Oxford are horrible examples, both from the point of view of appearance and utility, of the complete

lack of contact that had been allowed to occur between the architect and the scientist.

There are already happily many signs that this state of affairs is coming to an end. Science is being forced into architecture largely as a result of the necessity for new knowledge to cope with new materials. Another aspect of the same thing is the profound influence that engineering design, particularly of ships and aeroplanes, has had on the standards of architectural taste. At the same time developments which have taken place inside science—particularly those referring to the intimate structure of matter and to new physical methods for determining stresses—are capable of making it of far greater service to the architect than it could have been in the past. The work of the Building Research Station marks the beginning of what may be a new and fruitful phase of intimate collaboration. Nevertheless, almost everything yet remains to be done. The great developments of science in the last hundred years are still for the most part entirely unassimilated by the architects. Science can help architecture in an enormous variety of ways, and in doing so can itself profit from the problems that such collaboration is bound to raise.

Three Aspects of Architecture

The art of architecture can be considered to have three aspects: the formal, the structural and the functional. Actually, as the historical development of architecture shows, the order is the reverse of this, functional needs giving rise to structural problems the solutions of which fall into formal modes. But science comes into architecture in the first place to explain how things can be done, not what to do, so that the more conventional order seems more appropriate. In each of these what is required is a blend of the new knowledge that science can give with the aesthetic sensibilities and the practical considerations that rule in architecture. In the formal aspect of architecture, the freedom which the new materials provide raises anew the problems of shape and mass divorced from the normalising influence of well-established tradition. Here science, and particularly mathematics, bears the same relation to architecture as the theory of harmony does to music. No amount of theory will make a man a musician, but there can

be no doubt that the existence of musical theory has enormously enriched the possibilities of musical composition. Similarly in architecture, the mutual arrangements of the units of mass and surface in an architectural composition, be it a house, an office block or a town, which must in any case conform to certain geometrical principles, can be manipulated most competently when those principles are understood.

Symmetry

There are two underlying mathematical modes which have recently become more important in science, and are particularly applicable to architecture, namely, those of symmetry and topology. The only aspects of symmetry that are formally considered in architecture are those of mirror symmetry in elevation, and, to a minor extent, radial symmetry in plan, but there are far more symmetries than these. Any type of repeatable operation, whether it is a reflection, a turning or merely a translation in space, gives rise to a symmetrical structure. This will be so whether the parts that are produced are equal or diminished or increased in any regular way. Such kinds of symmetry have, of course, been found in nature and produced in art from time immemorial. An equal-spaced arcade, for instance, is a particularly simple example of translation symmetry. When it is modified regularly, as in some bridges, or in steps, as in Gothic cathedrals, the structure still retains symmetry, though of a more complex character, and the effect, pleasing or otherwise, which it produces is largely due to the degree in which the laws of this more complex symmetry are obeyed. There is only a finite number of possible symmetrical modes. In surface repetitions, for instance, such as those for pavements or walls, there are actually only seventeen different rhythms, all of which have been used unconsciously in art, but many of the more subtle ones only in the textile work of primitive tribes. In three dimensions the complexities are naturally greater. Here there are no fewer than 230 modes, most of which have certainly not been used up till now in architecture, but which might be made to produce new and significant effects. The importance of such developments at present is increasing because the architect is no longer tied to

the massive piling of rectangular blocks and can place his elements almost where he likes in three dimensions.

Topology

The importance of topology is probably even greater for architecture than that of symmetry. Topology, which is a rapidly developing branch of mathematics, deals with the spatial relations of elements independent of their actual or relative distances. It represents the analysis of the connectedness of different parts of space. Now it is principally in a functional aspect that the architect is concerned with connectedness. A problem of the greatest importance in any building is how people can get from one part to another, and this problem becomes of crucial importance in buildings of great size, where the simple solution of equally spaced corridors and staircases definitely breaks down. Practical topological analysis would enable the architect to choose a structure which achieved the greatest mutual accessibility compatible with the factors of appearance, stability and cost. In the larger problems of urban and regional planning, topological considerations naturally become even more important. It is interesting to recollect that the subject of topology itself derives from town planning. It arose from the problem proposed in the eighteenth century at the Russian Academy of Science as to how to cross all the bridges in St. Petersburg without crossing any of them twice. In town planning far less guidance can be got from tradition and common sense than in architecture proper. Urban districts have not grown up for the maximum convenience of their inhabitants, and to copy existing arrangements in new constructions is simply to perpetuate historic mistakes. The main value of these mathematical disciplines in architecture would be to replace intuitive and haphazard solutions by others that could be rationally arrived at. The general capacity of the architect would certainly be enlarged by his learning to think of his constructions in these more abstract terms. Nor would the advantages all be on one side. If architects were to take up symmetry and topology, these subjects would be brought down to earth again to their own great advantage, for mathematics long divorced from reality tends to become a very barren field.

New Materials

A much more practical and easily recognised connection between science and architecture is provided by the new developments in materials and structural principles largely due to science. Up till now, however, there has been far too little contact between the needs of architecture and the products of applied chemistry. The great changes that have occurred in architecture have not been due so much to the production of radically new materials as to that of old materials, such as steel or cement, in such quantities and at such a price that they could find quite new uses. But science has now so far advanced that the possibility exists of producing radically new materials and, what is even more important, producing them to specification. It is for the architect to say what are the properties which he requires in his materials and for the scientist to find or synthesise materials having these properties. This requires a rational appreciation on the part of the architect of what he is really trying to do on the structural side. Now structural elements in architecture are essentially adapted to three purposes only: those of support of weight, insulation and surface finish. In practical language, a building must stand up, it must be wind- and weatherproof, and should be good to look at, inside and out, as well. Originally these three functions were confused; the wall and the vault provided support, protection and appearance all in one. The whole evolution of architecture has, however, been to a separation of functions. The development of the mediaeval cathedral from the barrel-vaulted Romanesque church is a history of the breaking up of the wall into piers and buttresses and of the vault into ribs for the support of the edifice and the opening out of the windows with their tracery and stained glass to enclose the space and provide the decoration.

In primitive architecture strength was largely required to support the weight of the building materials themselves. At present the limiting factors are, or should be, merely the weight of the people and their chattels and the force of the external elements. For these purposes we have as yet found nothing better than metal, though the building metals of the future are more likely to be light magnesium or aluminium alloys than steel. Architecture must, however, first learn to use metal.

Most steel-framed houses are hardly distinguishable, except in scale, from the timber-framed houses of the fourteenth century; both exhibit an extravagant use of massive material whose main function is to support itself. The same applies to the problem of foundations. The earth, even in relatively stable countries like England, is a quaking sea. In a modern city, vibration produced by traffic has become a major annoyance. The modern large building requires not to be firmly founded in the earth but to be carefully insulated and to swim on it in delicate balance. Once again, in the words of the old Norsemen, the house must be a land-ship.

It is in the direction of insulation, however, that science has the most to offer in the way of materials. The outside of a building is required to provide protection against the wind, rain, dust, heat and cold. Interior partitions need do none of these things, but must deaden sound. There is no need, for any or all of these purposes, of Portland stone or brick walls. These are just megalithic encumbrances from a past age. The thinnest sheet of metal will defeat wind and rain, but the problem of a heat- and sound-insulating material has yet to be solved on a large scale. Already, however, such materials exist in nature and in the laboratory. The aerogels which are found in certain plant products, notably in the silicified pith of bamboo, can now be made in the laboratory as hard solids several times lighter than cork and practically perfect insulators against heat. They also have the incidental advantage of being completely fireproof. If such materials could be produced on a large scale, walls and partitions could be made from slabs weighing about five kilograms per square metre or less, which would reduce the structural burden of the framework to that of supporting floors.

A change more radical than the use of air-filled material would be to continue the development, already begun in France, and to use air itself as the ideal building material as being light, warm, transparent and costing nothing. Already, moving air, suitably aerodynamically directed, has been used as a substitute for the glass of locomotive engine windows, giving unimpeded vision and perfect protection against rain, snow or cinders. The same arrangement could be used in connection with air-conditioning plant for providing open windows with no draughts and proof against all kinds of weather. Indeed, it

might be ultimately possible to make most of the living parts of houses completely out of air, so that the people in them could enjoy all the advantages of being in the open without any of the inconveniences. The difficulties that have existed up till now, either in finding new materials or in finding uses for them, have been largely due to the separation between the pure scientists, the applied scientists and the architects. To a certain extent the Building Research Station and the committees which are associated with it are remedying this, but it is probably still true to say that the architect has extraordinarily little opportunity of appreciating new possibilities in these fields.

Function and Design

It is now a commonplace of architecture that the function of a building should play a decisive part in the consideration of its design. Nevertheless, the determination of necessary functions and of the means for carrying out these functions is not an easy task, and requires the intimate collaboration of the architect with a number of different kinds of scientists. The essential point is that the function of all buildings is preeminently social, rather than simply biological, utility. A church has the recognised function of being the background for complicated ritual observances, but so, almost to the same degree, has every building. It is, in fact, this essential ritual aspect of architecture that has, until recently, saved the architect from having recourse to the scientist. Because people's lives and their buildings form so closely a part of one tradition, all the architect was required to do was to provide pleasant, though always minor, alterations on well-known themes. Now, however, social forms are changing with a rapidity that quite outstrips the possibility of traditional architectural development, and the architect by himself necessarily proves inadequate to the task, as so many pseudo-modern buildings show. For not only are social demands changing; they are becoming at the same time more rational and definite. The architect is no longer building for the individual taste of a patron but for the requirements of a trust or a town-planning authority. For these purposes it is necessary, in the first place, to have much more definite views as to the function of buildings.

The development of functional architecture is in many ways

similar to the organic evolution of the higher animals. First, there is the isolated hut, fulfilling all human social needs at once; then the loose assembly of such unspecialised or partly specialised huts in the family or tribal village; then the house appears, which may be regarded as a partitioned hut or as an agglomeration of huts, each now with a specialised function. Houses in turn aggregate into cities, which have remained unchanged in principle from the dawn of civilisation almost to the present day. But now, with the development of large-scale architecture, a new unit is appearing; the building which contains many houses together as flats and many other specialised groups of rooms, shops, cinemas, etc., as well.

Each new organic agglomeration means new functional problems for the architect. The basic unit of functional architecture still remains the room, which may be defined as an insulated equipment space, supplied with communications and various services. It used to be thought that the architect's task ended with providing the four walls of the room with its door, window and fireplace; all the rest was furniture. Gradually, however, the functions of furniture have been taken into the structure of the room itself. Water, heat, light and now increasingly air are being supplied through the framework of the building. All this involves problems in the solution of which the scientist should have as much to say as the architect. Further problems arise in the proper grouping of rooms with different functions.

What we need for this is an institute of domestic engineering in which a number of different studies would be simultaneously pushed forward. We should want a sociological investigation as to the actual needs of family life with due regard to differences between families and the changing standards of human behaviour in recent years. This in itself is well worth the attention of architects. If houses are built to last a hundred years they may, however perfectly functionally designed, become extremely inconvenient to a new form of social life. The family house of the Victorians, intended to hold a dozen people and a half-dozen dependants, is transformed with difficulty into inconvenient flats for two or three people apiece. If we plan new houses for all incomes we may find them extremely inconvenient if, in a changed social state, the range of variation of income is reduced from some ten-thousandfold to a mere

tenfold. But even if we accept for the moment present estimates of social needs, it should be possible for physicists, chemists and engineers to evolve the most rapid practical way of satisfying them. We are apt to think that in the elimination of domestic drudgery all that can be done has been done in America, but what has been achieved there has been by mere rule-of-thumb methods. The greater part of the problem has still to be solved, and it can be solved much more quickly and much more satisfactorily by science. The general problem is naturally more complicated even than this. The existence of new and more convenient houses would in itself change social habits, and these changed social habits would, in turn, require further modification in the houses. One thing that will clearly be needed is a much greater elasticity. People have accepted fixed forms in their houses not because they liked them, but because there was no possibility of anything else. The houses of the future must admit of far greater possibility of alteration with the seasons and with the whims of the inhabitants. The possibilities of doing this easily and cheaply are latent in the new materials and processes that science could give to architecture.

Town Planning

The sub-units, rooms, houses and buildings themselves form part of the great unit of a modern town. The town, it may be said, is no business of the architect, it is simply the environment to which he must adapt his houses. But the essence of any living organism is that while it adapts itself to environment it simultaneously modifies it, and we shall never get good buildings unless we can make good towns to put them in. This is, of course, far more a social and political than it is a scientific problem. It may well appear to the architect, as it does already to many scientists, that he is at the moment attempting an impossible task. The requirements of modern civilisation—production, communication and the whole business of living—demand a degree of co-operation and integration of human action that is completely incompatible either with the relics of the anarchy of private property or with the monstrous growth of monopoly and class privilege that has grown out of it. Private property and vested interest between them are sufficient at present to block any rational approach to a functionally

satisfactory modern town. Here and there enough can be done on a small scale, even in this country, to show what could be done on a large scale and, in that way at least, the architect has a possibility of showing what the world is losing in the facilities for a good life by its adherence to anachronistic economic and political forms. The scientist is in very much the same position. He also is cramped, in the possibility of his work, by the same factors. For that reason, if for no other, architects and scientists should come together in putting forward the claims for a better world.

For the moment, however, they are likely to have enough to do with preserving what is good in the world as it is, for the immediate prospect for architecture and science is the dedication of both of them to the service of war. The scientist is to be concerned with producing the means for blowing up houses and burning and poisoning the inhabitants, and the architect with making houses to which this cannot happen. The association of architecture and war is certainly not new, but it might have been hoped, up to a few years ago, that society was evolving in a direction in which architecture was being liberated to serve human comfort and amenity and had finally left that phase in which it was mainly required for defence. We can still see, in a few remaining mediaeval towns, the cramping effects that architecture primarily designed for defence can have, but this is nothing to those which a logical preparation for modern war would imply. We should be obliged to return essentially to the state of cavemen. Only buildings underground, or so heavily armoured as virtually to be underground, could be made to stand modern war conditions, and even in them everything would be a network of gun pits, casemates, safety passages with air-tight locks, food-stores, casualty and decontamination rooms, while for the majority of the inhabitants life would become little different from prison routine. The hopeful possibilities of the collaboration of science and architecture do not lie along this path. If we are to achieve the synthesis that is necessary for the realisation of the new possibilities, it will not be sufficient to have good scientists and good architects, it will be also necessary jealously to preserve and extend peace and liberty.

What I have tried to show in this brief survey is that architecture and science are not two exclusive disciplines, that neither

can fully flourish unless it retains a living contact with the other. In the formal, the structural and the functional aspects of architecture science can point the way to new processes, new materials and new arrangements. It is for architecture to use these and combine them into its living tradition. In its turn, science stands to gain by the widening of its field of inquiry and by the appearance of new problems to solve. Finally, since both architecture and science depend for the fulfilment of their latent possibilities on the development of a state of society compatible with that realisation, their interests are jointly involved in securing it.

From the *Journal of R.I.B.A.*, xliv, No. 16, 26th June 1937

SCIENCE IN ARCHITECTURE[1]

IN trying to cover such a vast subject as this, I shall inevitably be very general. I do not want to talk about the details of the application of science to architecture, and I particularly do not want to do so tonight because I am going to discuss some of the more detailed and practical aspects later on at a meeting of the Architectural Science Board. What I hope to do tonight is to show what a very large change has come over the relations of science to architecture in the last few years, particularly as a result of war experience.

As a scientist whose connection with architecture was extremely limited before the war—limited to the fact that architecture made use of substances the structures of which as a crystallographer I was studying—I at first took altogether too narrow a view of the relation between the subjects. I published in your *Journal* before the war a paper on Architecture and Science[2] which I now think exhibits that limitation. It was a limitation extremely common to the general relations between science as studied in universities and research laboratories to any of the arts and techniques which are the basis of civilised life; that is, the scientific aspect was extremely abstract and

[1] A paper read to an informal meeting of the Royal Institute of British Architects on Tuesday, 12th February 1946, the President in the chair.

[2] See above.

touched the practical aspects only through a large number of intermediary persons and organisations. We thought of science as dealing with those parts of the subject that could be directly seen to be scientific; that is, taking the example which I gave of the actual structures of materials, the factors which determine the strength of bricks or concrete or steel or, going a little further, the simple physical conditions that rule in buildings—such things as the passage of heat and of noise. All those are what may be called direct applications of science to subjects involved in architecture, but they are not, in my opinion now, really the essence of the scientific aspect of architecture itself.

In the same way, at the beginning of the war the scientist was conceived of as a person who produced and developed scientific weapons—scientific in the narrow sense; that is, the kind of weapons which if you did not know something about science you could not effectively use. You do not need science to use a rifle or a machine-gun, but science of a sort is needed to work a Radar set. In the early days of the war, the whole emphasis of science in war was science in relation to scientific gadgets. It came about most of all, of course, in the aeroplane, which is scientific almost through and through. But, as the war progressed, it became noticed that it was not so much the scientific gadgeteering side which was important; it was the scientific approach to the problems raised by military situations generally; problems raised in the factory, production problems, planning problems in the general preparation of war weapons, and finally, towards the middle and end of the war, the problems of actual operations. While this was going on, organisation was drawing the scientists more and more closely in with the practical people. It was an experience which was common, I think, to all branches of science, and led to an entirely new and wider view of the relations of science and practical things.

As far as the scientist was concerned, it meant that the divisions between the sciences broke down. We worked very much in teams of scientists which completely crossed the old boundaries. Of course, scientists in adjoining fields have worked together often enough—physicists have worked with chemists, and so on—but in this new way of working there were not only chemists working with physicists but physicists, chemists, biologists, sociologists and economists all working together on particular problems.

One example of the kind of thing with which we were faced, and a problem which referred directly to architecture, was the requirements of the Ministry of Aircraft Production work to make factories with the following characteristics: they were not to be visible from the air; they were not to be capable of being destroyed to any serious extent by high-explosive bombs; it was to be impossible to set them on fire; they were to be so designed as not to interfere in any way with production; and they were to be made with no wood and with a minimum of steel and concrete. Now, that is a large, complex problem, and it was solved in a very integral way. At the Building Research Station a group of a dozen or so people was brought together, each of whom had a special contribution to make in his own field. The A.R.P. experts were called in on the subject of layout with respect to bombing; the fire experts were called in on fire prevention; the production engineers on the production layout; and the building research people on wartime economy in materials. It was perfectly possible to get those diverse people together and to produce, as a result of the different criteria laid down by different people, something which not only satisfied the requirements but was a good deal better factory than if it had been made to satisfy the rather simpler requirements of peacetime.

It is a fact that human beings do not solve problems or attempt to solve problems unless they are put to them in a very drastic way. It is much easier to draw a factory on a drawing-board in nice rectangular blocks, arranged in a simple pattern. One such factory was built during the war; it consisted of four blocks, large blocks of about 100 ft. by 80 ft. placed in a row. An intelligent German airman came along and dropped a bomb neatly into the centre of each block on one single run, and that factory was out of action for the best part of eighteen months in consequence. It was not that the factory had to be made like that; it was because a certain amount of time had been saved on the drawing-board at the expense of everything else.

The bringing to bear of combined special intelligences on a problem is the essentially new contribution of the war—the collaboration and co-operation of people with different technical and different scientific contributions to make. It happened by force of circumstances in the war, but it is likely now to become

established as a kind of tradition. It is the pattern which will enable us to tackle a large number of other problems.

It was not really necessary in the past, because what is much simpler than the co-operation of a number of different experts is to have all the co-operation in the mind of a single person. The architects of the past were both scientists and architects. You cannot imagine that any of those who did the big architectural, engineering jobs of the past were not in part thinking scientifically and often working things out scientifically. One does not know what scientific research department Anthemius had, but it must have required a considerable amount of thought to attempt constructions of such magnitude with relatively unknown materials. The architects of the seventeenth and eighteenth centuries were either themselves scientists, like Wren, or worked closely with engineers who carried out researches of their own on the strength of materials and the suitability of various types of construction.

Architecture today is going through another major transition phase, one which is characterised by a change in two things at once—it is not accidental that they should go together—a change in requirements and a change in materials and methods. A very similar type of transformation, though not nearly so big, was that which occurred at the close of the Middle Ages, when the traditional stone architectural construction, almost exclusively used for churches and castles, gave place to a construction very largely in brick for the mansions of the new wealthy class. That transition made an enormous break in architectural practice. It was a break which was eased by the fact that it did not occur in all places at the same time. With foreign assistance we were able to execute the change in this country more easily for example than was the case in Italy. There was, nevertheless, a complete change in objective—the house for comfort—first of all the magnate's house, and then the ordinary house—and a complete change in methods—really a reversion to much simpler methods than the extremely ingenious and intricate methods of the Middle Ages.

Now we are faced with a transition which has both those elements in it. The transition is to building for human requirements and human utilities, conceived of in a conscious way, and doing so under conditions which both provide and require new materials and new methods of construction. There is a differ-

ence between this and the transition of the past, in that this is a very much more conscious transition.

There is an enormous advantage in tradition. The advantage of tradition, particularly for the architect, is that once it is established, once it is known in a general way how materials will behave and how structures will fit together, the architect can become very much more of an artist and less of a technician. Once the instruments are there, once the rules and orders of architecture are firmly laid down, he can become almost a pure artist, and simply combine them to produce more and more novel or pleasant or merely tasteful results. With tradition there is a definite growth of new forms, but the growth occurs by the old process which belongs to the organic world, the process of the survival of the fittest. If someone tries something which is a little too new and it does not work he is eliminated. The trials are done full scale, and the thinking, so to speak, is done on the job. That kind of traditional change does work, but with definite limitations; and we have now passed them. The limitations are that the rate of change has to be sufficiently slow and that the materials and man-power are available in sufficient quantities for the jobs in hand. Neither of those conditions holds now.

We have in this country and in very many other parts of the world an enormous building programme, concentrating in the first place on housing. This concentration on housing may be considered to be a war measure, but in fact it has been the dominating feature of British architecture for a long time. It may be that from the point of view of the employment of professional architects housing did not play such a large part, but from the point of view of actual building effort it played an enormous part, and in the next few years is likely to play an even larger one.

If we consider that the whole direction of architecture is to be turned for a good many years to come on the provision of dwelling-space, we shall see the kind of problem which cannot be solved in a purely traditional way. Our difficulty is that we want houses very badly, we want them very quickly, and we are likely to be short of man-power to an extent of which there was no experience in past years. We have always lived in an era of potential, and usually actual, unemployment on a large scale, and the question of man-power has very seldom arisen. Simi-

larly, the question of availability of materials, which boils down to a question of man-power in the material-producing industries, is also likely to be acute. We have therefore the pressure from the needs side to build the houses and the resistance from the means side as to materials and men; and it is just at that point that the full collaboration between the architect and the scientist is most needed.

The problem has to be seen as one integral problem in all its aspects, and it has to be broken down in such a way that it becomes a series of manageable problems that never lose touch with each other. Those problems have long-term and short-term aspects. While we are dealing with the immediate shortage we have, as we had in the war, to put on one side a number of things which seem to us very much better solutions. Take what is clearly by far the most important one—the actual materials, the basic constructional materials for houses. It is fairly clear now that the traditional materials for houses, brick and timber, are not the best materials for the job, but in fact we shall use them; we shall use them because it will take longer to get the new materials into action than we can afford to wait for the houses. But even if we do largely put that solution to one side, we do not forget it; we are learning all the time, in producing the marginal houses, to lead up to the big revolution in house construction. We would not come to that point ot view on purely technical considerations.

In order to see what the problems are, it is necessary to begin not with the house and not with the building materials but with the people who live in the houses. It is an extraordinary thing that although we know in science a great deal about the most obscure and remote subjects, about the interiors of the stars and the centre of the nuclei of atoms, we do not know scientifically some of the most simple things that, as you might say, everybody knows.

Take one extremely striking example, but a true one: we do not really know what women do in houses. Women all know what they do in houses, or they think that they know, but when it comes to the facts, it is extraordinarily difficult to get them. That energetic body, Political and Economic Planning, in producing a very elaborate and useful summary of domestic gadgets, gave in the introductory material a table which purported to give the amount of time which the average housewife

spent on various avocations—cooking, cleaning, washing up and so forth—and divided the week accordingly; but they admitted that this table was based on an inquiry into the work of only fifteen housewives. In fact we simply do not know enough about what the house is used for.

The problem, however, is a little more complicated than that. Suppose we did know, suppose we had the most elaborate survey of what people do in houses, we should still not know what kind of houses we wanted. We should learn a great deal; we should learn where things were worst and where the most wasteful and unpleasant work was done, and we might get ideas for making improvements; but we must remember that all the people who could give us information are living in actual houses, essentially traditional houses, and the whole of the information that they could give us is information relative to houses of those kinds, and not to potential or improved houses. In other words, to get the real answers as to what you are designing a house for, you have to design a house—in fact a large number of houses—and put people in them and see how they get on. An experimental as well as a sociological survey has to be undertaken in order to find out the very things that we want to begin with—the requirements that a house has to fulfil.

Many of you may say to me, "That is not very important. We do not need any scientific research to know what a house is for. Everybody knows what a house is for; a house is to live in, to keep out the rain, to be warm enough for people not to be positively uncomfortable and to provide the background for living activities, some of them of a semi-industrial kind, like cooking, and some just sitting around and playing." It will be said that everybody knows that, and that, in a sense, has been the way in which the problem has been presented on the traditional or architectural level.

Actually, however, if you consider those very simple requirements that I have mentioned you see that they themselves involve a great deal of scientific examination. If we could determine within limits the amount of air, and the amount of heat, and so forth, that are needed to provide a satisfactory, optimum, healthy atmosphere we could start in an engineering way to provide them; but we do not even know those things. When I say we do not know, it does not mean that we are not

trying to find out; but we have not found out yet. We do not even know what fresh air is. Everybody recognises fresh air when they have it, but we do not know what it is, we do not know how to measure it or necessarily how to provide it. We know some ways of providing it, such as going out into the open, and we know the traditional method of opening all the windows wide, but if we do that we produce draughts. We should like to have a house where we could have all the advantages of fresh air without any of the disadvantages. That is not an impossibility, but in order to achieve it we shall have to do a good deal of research and a good deal of more or less full-scale experimentation.

In the same way, we do not know some of the most important things about heating. We do not know whether it is better to be gently warmed by an atmosphere at a medium temperature or to have an atmosphere at a much lower temperature and have a constant stream of radiation on us. One solution, from the other side of the Atlantic, is to say that the desirable kind of atmosphere is the atmosphere which people will pay to be in. We know that people will pay to go to Florida, to the south of France, and to Egypt in the winter. In all those places there is comparatively cool air and bright sun, and great numbers of people seem to prefer those conditions; at any rate they do not pay nearly so much to go to the mild dampness of the west of Ireland or the north of Scotland unless they are feeling very energetic and nature-loving. You can produce those conditions in a house. It has been done by providing a radiating surface with fairly short infra-red rays uniformly, so that you do not find, as you do with an ordinary coal fire, that there is only one point where you can be reasonably warm, and you freeze if you go a little further away or boil if you go a little nearer. With parallel heat you are just as hot in one place as in another, and that is the great advantage of sunshine.

I give that only as an example of the problems which we have to solve even in elementary physiological matters. We have to do much more than that; we have to solve the human problems of living in houses. There is the question of how many rooms are occupied, and of whether when we demand a large number of houses we do not really let our social habits make terrific demands on our architecture. If a census were taken at the present moment of how many rooms were actually being

occupied of the existing rooms which are furnished, it would probably be found that it was between one-half and two-thirds, at any one time one set of rooms and at another time another. That is only a guess. There is a tradition that that is necessary, because it has always been done; but if we could have suitable heating and ventilation we could find how to make the maximal use of the space available. The family might be spread out a little more among the rooms of the house and more privacy provided if we had suitable heating. That is only one of the problems to be investigated; to solve it and all other problems of requirements we need a combined architectural and scientific team, basically sociological, to investigate the requirements.

When the requirements are known, we begin to see that they involve problems of a technical kind which are not necessarily those which are solved by traditional methods. It is fairly clear that in order to be able to control the atmosphere and the heating of a house, however we may desire to do so, we have to be able to prevent heat and noise getting into areas where they are not wanted. In other words, we want insulation, and we want insulation as insulation. In the past, we have combined structure—the "firmness" of your architectural trinity—with insulation. However, far the best material of any for insulation is air, and what we really need to do in insulation is to get air cheaply. A brick has a good deal of air in it, but not nearly enough. Cork is perhaps the best that nature has done in the way of providing air suitably done up in small packets, but the modern foamed glass is probably on the way to the best solution.

If we want insulation, if we want walls, ceilings and floors which keep out heat, either a fibrous structure or a cellular structure has to be provided. With a fibrous structure it is easier to do, but while we stop heat we probably do a good deal to make the entry of moisture easy, and particularly, of course, capillary moisture; therefore, having provided insulation against heat we have to double it with insulation against moisture. Problems of a very serious kind have come up in this connection in prefabricated houses. On the other hand, the cellular type protects perfectly against moisture, but perhaps too much against anv kind of gas or vapour movement; in other words we have sealed up our walls and have to make other arrangements for ventilation and use other methods for

getting rid of vapour. What I want to emphasise is that there are now possibilities of relying on insulation and cutting down the actual weight of material in a house by a factor of at least ten at present, and I should not be at all surprised if in a measurable time we reach a factor of a hundred. A house which at present weighs about 140 tons can be brought down to a weight which is no more than is needed to support the wind pressure and the live loads.

When we try to solve this problem, however, we come across other difficulties. There is the very elementary difficulty which has held these things up in the past—that of cost. We could probably even now build an extremely light house which would be very efficient, but it would also be very expensive. We are therefore driven to another straightforward technical problem—how to get these materials, basing ourselves on low cost. There are two factors in cost: the abundance of the raw material and the simplicity of the processes of working it up. All kinds of materials which have hitherto been considered as waste materials may very well be used for these purposes. There are vegetable materials such as straw and even bracken, and old vegetable materials like peat, which have enormous possibilities in building once the process of working them up into a suitable form have been properly established. There you pass immediately from the research establishment to the manufacturing problem of production. In addition to materials of the vegetable type there are the great varieties of silicate materials, from the glass type to the new foamed concrete type. They provide completely new materials with which to work. The revolution of the early twentieth century from brick to reinforced concrete was, of course, a revolution of engineers, a revolution dealing with heavy building, with bridges and civil engineering construction generally. It is the light insulated materials which are going to bring about the revolution on the more domestic side of architecture.

If you have your new materials and if you know what it is that you want to make, you have still the job of making it. Here more than anywhere else is the proper field of the architect. The architect may say: "The scientist may tell us some things about what a house should do that we might not have been able to discover by intuition, and may even provide us with new materials, but the actual building of a house consists

of the laying of stone on stone and brick on brick; that is the way in which houses have been built and always will be."

We know already that a good deal has been done to get away from that, but what has been done has often been as unintelligent as the tradition, with less excuse. The iconoclast who comes across people taking small prefabricated units such as bricks and putting them one on top of the other with great artistry but considerable slowness is apt to ask: "Why not do the whole thing in one?" Edison, with a very simple mind, said: "Why not build a mould for the whole house, take some concrete, pour it down the chimney, and there you have your house?" He did it, but it was not a success, because he did not know and no one knew at that time that a house built of solid mass concrete poured in would not be very nice to live in even if it were cheap to make, and it was not cheap to make because of the mould. Nevertheless, the method is not a bad one and is used today with light aggregate or no-fines concrete. However, the idea of going all out to do the exact opposite of the traditional method is just as unscientific as the traditional method itself.

The real problem is to analyse bit by bit what the operations that occur in any building are and to see how those operations can most advantageously be carried out so as to give the minimum cost, the maximum speed—because we are in a great hurry at the moment—and the minimum man-hours on the job itself. It is that acid test which determines whether any method of prefabrication is worth while or not. You lose as well as gain a great deal by prefabrication. You lose in the factory through the overhead costs of factory work. There are all kinds of difficulties, like those faced in the aircraft industry, of getting the parts to fit. Moreover, you work initially against one enormous disadvantage. The great advantage of tradition is that everybody knows how and what they have to do; the great disadvantage of new methods is that new people are doing new things, and they are bound to be inefficient at first.

Here again, however, this job can be tackled and is being tackled. In the Building Research Station and in various groups of houses which are being built under the direction of the Ministry of Works, we are trying to treat the problem absolutely rationally and without prejudice. There is a very natural difference between the person who wants to build in a

certain way and the scientist or the government department responsible to the community. The first is really trying to sell something. That is a perfectly legitimate thing to do, and he will succeed in doing it only in the long run by giving satisfaction; but his interest is necessarily biased in favour of what he is trying to sell, whereas we have to adopt a critical attitude. We have to see what each operation costs, and we have to find the sequence of operations which gives the best results. That may mean something between the fully prefabricated house and the traditional house.

After all, there is a great deal of prefabrication in the traditional house—doors, windows and many other things. Take a floor: is it easier to build a floor plank by plank on its joists in the house, or to build it somewhere else and take it to the house? In the latter case, what size of floor unit is the most economical to make? That means the balancing of a very large number of factors. It means balancing the prime cost between the factory method and the *in situ* method. If all that is done in the factory is exactly the same as what is done in the house, then the cost will be heavily weighted against the factory; but even if the factory, by using jigs and machine-tools and so on, is able to do it very much cheaper, there is then the much greater transportation cost of transferring the larger units from the factory to the site, and that may outweigh the advantage. It is a very difficult and intricate subject, but a subject which can be tackled, and which can only be tackled, by a through-and-through scientific analysis.

I have given all those examples to illustrate the much more extended kind of way in which science is coming into architecture in these days. You may say, and have some justification for saying, that it is not science, and others may say that it is not architecture; but, whatever it is, it is the way to get results in a complex civilisation such as we are moving into today. We shall have to take all these different things into account, and we shall have to get a kind of combination of scientist and architect to carry this out. It is not that the scientist is trying to take away the function of the architect or to substitute something else for any part of that function. What the scientist is really doing is adding to the traditional materials and methods of the architect, not just new materials and methods but a way of finding new materials and methods. It is introducing

foresight into what was previously something just going on of itself. When the rate of change in society gets beyond a certain limit, it cannot be left to the individual genius of the architect, though he may himself have scientific training; you have to bring in the scientist, because he is the person who weighs up and assesses the results of any change.

How this is coming about is now fairly well established. There is already a very close liaison between scientists and architects in the Ministry of Works and throughout the Department of Scientific and Industrial Research. Every single example that I have given tonight is drawn from the experience of one or other of the actual workers in the Ministry or in the Building Research Station. The startling thing about it is that there is no individuality, nothing that is the exclusive work of one person or another. That integration, however, can be successful only if it stretches far beyond the Ministry and the Research Station into the actual work which is being carried on up and down the country. To achieve that, we have to get the willing collaboration and understanding of architects, builders, building trade workers and scientists. It is for that reason that I particularly welcomed the formation and work of the Architectural Science Board. When it started—and I had the privilege of being asked to join it when it was the Architectural Science Group—we had only the idea of a programme, and we could not do any research, but only think of the kind of research which we should like to have done. Now we are starting to do the research, and from now onwards we must begin to use it.

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ORGANISATION OF SCIENCE

INTRODUCTION

THESE three essays deal with the more restricted subject of the organisation of science itself. The vast growth of scientific effort in the twentieth century, and particularly during the war, has made the question of the internal organisation of science a vital one for its survival. It has necessarily also been a field of the most violent controversy, waged primarily between those who cannot see the possibility of any type of organisation that will not destroy the spontaneity of science and consequently its capacity to increase knowledge by original discovery, and those on the other hand who consider that without organisation discovery of any sort will be impossible for lack of means and men. These essays attempt to show that this contrast is unreal and that the organisation of science is not a contradiction in terms, but can be done without hindering individual initiative. Indeed one of the major purposes of organisation is to give initiative and originality the opportunity to express themselves. Much of these essays is concerned with the work of already existing organisations such as the Association of Scientific Workers and the more newly formed United Nations Educational, Scientific and Cultural Organisation (UNESCO) and the World Federation of Scientific Workers. Since the war many of the suggestions made in these essays have in fact been accepted and all great industrial nations are now treating the organisation of science as an essential part of state administration. Consequently some of the issues raised in these are no longer live ones, but they should express, for scientific readers at least, something of the background of controversy that still goes on.

ORGANISED RESEARCH FOR PEACE

PIECE by piece the story of what scientific research did in the war is being released. The public is being allowed to learn how Radar was developed, how the magnetic mine was countered, and how scientific were the preparations for D-day and the crossing of the Rhine. But the great lesson of science in the war is not to be found in separate feats of ingenuity; it lies rather in the total and increasingly integrated effort of scientists, engineers and fighting men to discover and solve the indivisible problem of war. It is true that many of the solutions found for war problems are also solutions to peace problems. D.D.T. and penicillin, though both known before the war, owe their accelerated development and mass production to war needs and, between them, represent the greatest gift to suffering humanity that any six years of human history has produced. The engineering and electrical devices of the war will also have revolutionary peacetime uses. All these together, however, cannot compare in their potential contribution to human welfare with the new approach which has been evolved in the war in the directing of scientific research and in linking the results of that research with practical action. The ten thousand odd scientists who have been working in the services and the service ministries during the war have acquired in the course of it sufficient experience of that way of working as would enable us, given proper backing and direction, to accelerate immensely the rate of mechanical, biological and sociological progress of this country and of the world.

There is nothing magical or abstruse about these new methods for they merely represent an extension of rationality over wider fields than hitherto. It was possible for the first time in the war to provide comprehensive studies of needs and to draw up research plans to meet them: to develop an attitude of deriving what has to be found out from what has to be done. Further, because the war effort was so multifarious and involved everything from human training, medicine, agriculture, engineering to physical sciences, it was possible, and indeed necessary, to bring out and use the relationships of all

these different disciplines. The unity of science was becoming expressed for the first time in practice.

Now though the problems of peace are even more various than those of war they also must and can be grasped as a whole and attacked in an orderly way. Indeed, if they are not so dealt with, the future will be very grim indeed, because the war itself and its resultant effect on world economy has made a continuation of our old haphazard development of industry a certain prelude to the disappearance of Britain as a major industrial country and consequently as a country having any important voice in the affairs of the world.

The alternative is to make a definite, conscious effort to secure an all-round improvement of the work and life of the people of Britain with due regard to their relations with the rest of the world. Such a task as a whole is, of course, the dominant political and economic concern of our time—it is a task for the whole active working population; but scientific research has a very necessary and, indeed, decisive part to play in making it fully effective. No amount of goodwill or organisation will suffice to raise the productivity of the country and the standard of life unless the technical methods of production are radically changed, and this can only be done by scientific research.

In happier or idler times it might have been sufficient to throw the field open to the efforts of voluntary curiosity or ingenuity; if we had a large number of scientists, a small number of problems and ample time, some of the scientists would find the solutions to most of the problems sooner or later. And such a system—because it is no system at all—has the inestimable advantage of being beyond criticism as everyone can do exactly as they like and no one is responsible. Unfortunately the actual situation is the reverse of this. We have relatively few scientists, there are an overwhelming number of problems and there is no time to be lost. Some form of integrated attack on the whole set of problems must be devised to get the best results most quickly and economically so as to use our very limited scientific manpower to the utmost. This does not mean, as the more superficial or bigoted anti-planners seem to think, that every scientist must be forced by a kind of know-all directorate to settle down at once to solve practical problems. What it does mean is that a scientific study has to be made of the whole field of productive effort so that an

organically sound and healthy body of scientific research can be made to grow and to propagate itself increasingly through an intelligent system of education and training.

We have in this country progressed quite considerably in the direction of organised scientific industrial and biological research. The departments under the Lord President of the Council, who is a kind of *de facto* Minister of Science—those of industrial, agricultural and medical research—cover in principle most of the fields of human acitivites. The cover, however, is still very attenuated; until the war most of the work done was confined to dealing with isolated difficulties and problems arising in factories and farms rather than in developing new methods and opening up new fields of enterprise. The end of the war is certainly being marked by a new outburst of research effort; new industrial fields are being covered, for instance, shipbuilding and internal-combustion engines. Further, as a result of the war, the habit of attaching scientific advisers and scientific advisory committees, which began with the service ministries and the Ministry of Food, is now spreading to other ministries such as the Ministry of Works and the Colonial Office. The outline of a new system of research organisation is becoming visible. Each modern ministry of state is an organisation responsible for one whole aspect of human existence—transport, food or education. The addition of a scientific section means that the activity of the ministry need no longer depend on the routine of an office, on the vagaries of a minister's career or on the vigour of critics in the House of Commons. The whole field of ministerial activity can be critically and quantitatively examined to discover the problems and to set about solving them. The ministries, as organs of state, are the servants of the people: their work begins in finding out what the people need and, having found this out, they must set about discovering the best means of providing it. Scientific research is the new and sure way of doing this. But the benefits which its use may indicate may not be realisable within the current limits of the social and economic system. Once that is apparent, it becomes a matter for the people themselves, through the machinery of democracy, to alter that system.

Human needs are extremely various and the means of satisfying them more various still. If, for instance, we try to provide human needs for housing, we immediately find our-

selves involved in the provision of hundreds of materials, the manufacture of which touches on all aspects of physical and some biological sciences. We are not only concerned with the complex processes of building the house but in the even more complex activities that go on in the house once it is built—the cooking, the tidying, the cleaning. Thus just one aspect of human living already involves a great number of problems referable to distinct scientific disciplines. Now the solution of each of these problems has a range of use which extends far beyond the particular human need where it first arose; thus, for instance, the problem of plasticity of clay may arise as part of the need for better bricks or sanitary ware, but it is equally important to the metallurgist for his refractory furnace linings, to the electrician for insulators, to the road-maker in soil mechanics, and, most of all, of course, to the farmer. Now it would be absurd to build up sets of research institutions directed to the needs of a particular user without regard to the other users. This has, of course, been done in the past through the mere lack of co-ordination, but what was tolerable then, at the slower tempo of advance, is quite intolerable now. We cannot perpetuate isolations deliberately, however traditionally they have arisen. We must, on the contrary, devise a general system of research by which the more important detailed problems, each of which calls on a large number of fundamental sciences, can all be solved simultaneously by a single set of basic research institutes.

It may very well be that certain fields of knowledge, because of their particular attachment to some human need, can remain primarily in the field of that department of activity; soil science, for instance, in a way belongs to agriculture even if civil engineering has a large call on it. Nevertheless what is emerging is a dual set of research bodies based on two complementary principles—the user requirement which fixes the division of the more applied branches of science, and the intrinsic or natural subject which fixes the division of the more fundamental branches of science. Between the two there may also have to be a certain complex of intermediate junctions which may gather together, a series of demands from several user sources, and farm out scientific problems to several fundamental research bases. Thus, for example, an "Institute of Fibres" would serve on one hand textile, paper and building

industries research, and, on the other, maintain relations with botany, zoology, colloid sciences and physics.

Such an organisation of science is not something imposed by the state on the scientist by arbitrary dictation: it arises of itself once the problems of a productive society are logically envisaged and, in fact, is but a purposeful rationalisation of the traditional unplanned developments of the past. Its formulation, however, does remove a great deal of mysticism from our conception of scientific activities. There has been for at least a century a genuine fear on the part of academic scientists that the applied sciences were going to supplant pure sciences entirely, and it is behind most of the opposition to the very idea of the planning of science. This fear is baseless; any planning of science must enhance rather than diminish the relative importance of the fundamental sciences. They would have to continue to be studied as distinct though related disciplines, even if we were only concerned with extracting from them the greatest practical value in human betterment. If in addition the intrinsic value of fundamental science in deepening our knowledge of the world and society is fully recognised, its position in a planned society is doubly assured. In fact the fight between the planners and the anti-planners in science—a fight almost entirely of the latter's choosing—is an altogether unreal one. If we say "Fundamental sciences must be studied because they are useful and, in addition, have intrinsic value," rather than "Fundamental sciences must be studied for their own sake and, in addition, are found to be of use," it is because the practical approach will in fact provide more funds and draw more people into pure science.

Organisation of science does not mean restriction of scientific freedom. On the contrary, it enormously extends it. Freedom in science has in fact been restricted, ever since modern science started, by the elementary limitation produced by lack of money. This has meant not only that many brilliant and productive scientists of the past have had to spend a great deal of time at hack jobs to earn their livelihood, but also that a far greater number of potential scientists have not been able to enter science at all. Further, through the lack of proper organisation, scientists have worked without fruitful collaboration with others and often without the knowledge which would have been vital to their own researches.

It was this feeling of isolation that led to the great movement towards scientific organisation in the seventeenth and eighteenth centuries which culminated in the foundation of the Royal Society and the various Continental and American Academies. Such bodies, however, are not adequate to the needs of the day; to free science effectively for its task means placing at its disposal a much larger share of the productivity of the community, or, to put it a different way, it requires that a larger proportion of the population should become scientists. As we see it now, this proportion will always be small, something under five per cent, but the provision of five per cent of the national income for science in Britain would represent a twentyfold increase in its present expenditure on civil scientific research and development. Such expansion, however desirable, cannot be achieved more rapidly than men can be trained and acquire experience. So the more modest sum of some £24 millions a year, advocated by the Association of Scientific Workers, which is a quarter of one per cent of the national income,[1] seems a reasonable figure. What can be done is shown by the example of the United States where some $500 millions, or between one-half and one-third of one per cent of the national income was spent on scientific research annually in the war years. It is proposed in a letter from Dr. Bush to the

[1] The National Income at the period in which this was written was approximately £9,000,000,000. Since then the allocation to science has been greater, as given in the Third Report of the Select Committee on Estimates (132–1, H.M. Stationery Office). The following table drawn from the Select Committee's Report gives the expenditure:

	£ (millions)	£ (millions)
Military		
Admiralty, Ministry of Supply		60·4
Government-sponsored Civil Research		
D.S.I.R.	3·1	
Other Departments including Post Office and miscellaneous grants	2·8	
Agriculture and Fisheries	2·2	
Medical	0·7	
Dominions and Colonies	0·5	
		9·3
Grants to Universities		
Scientific Research		1·7
Industrial Research as estimated by the Federation of British Industries		30·0
Total Civil Research and Development . .		41·0

It will be seen that about ½ per cent is devoted to civil research, mostly industrial, and that sum could be more than doubled without cost to the taxpayer by reducing military research.

President of the United States that a national research foundation responsible for basic research and the training of American research workers should be set up with an initial expenditure of $10 millions rising to $50 millions per annum.

It is of course true that to provide money and personnel for science is by itself not enough: the scientific effort will not succeed unless it is democratically organised and imbued with the spirit of inquiry and the purpose of advancing human betterment. These conditions, however, largely exist already. The war has shown both the capacities for organisation and the keenness of British scientific workers. No doubt, once the stress of war is removed, it will be possible to achieve more democratic modes of scientific organisation than heretofore, enough to satisfy all but the small anarchistic minority of those who dread organisation as a possible restrictive factor for individual freedom of inquiry. No one is aiming at restricting this freedom, least of all those who have in mind the welfare of science and society. They are fully aware of the irreplaceable value of individual initiative in discovery and they will want to foster that initiative to a far greater extent than hitherto.

The concrete tasks that lie before British science in the post-war years are determined by the previous development of British science and industry and by the unique position Britain has come to occupy in the modern world. For its area and population it represents a higher concentration of industry than anywhere else in the world. Its economy is unbalanced in the sense that its agricultural production, efficient as it has become, cannot provide for its population. In fact Britain does not stand by itself: it is a metropolis of much of the undeveloped regions of the world. Some of these are to be found in the Commonwealth and the Colonial Empire but many lie outside in the Middle East, China and South America. This position is to a great extent the result of a series of historical accidents culminating in the fact that the industrial revolution was born in England; but the course of past events does not guarantee its continuance. First of all, absolutely, Britain is no longer the most important industrial producer in the world; more significantly it has also lost the lead in the productivity of its workers. Further, the spread of science and industrialisation is now beginning to reach the backward countries, which, as the examples of Japan and Russia have

shown, can transform their techniques much more rapidly in the twentieth than was possible in the nineteenth century.

The situation that has to be faced now is one of a world tending towards a common high level of industrial productivity and increasingly scientific agriculture. The welfare of Britain depends on its being able to adapt itself to the new world economy and, indeed, taking a large part in bringing it about. Now this cannot be done by a blind adherence to the past traditions of British industry and economy. Simply to continue the manufacture of accepted lines of consumer goods for export will get us nowhere. It was the increasing failure of our attempts to do this in the interwar years through tariffs, Ottawa conferences and general industrial inertia that provided the background for the dismal policies of appeasement.

What must be done instead is, in the first place, to concentrate on the development of the basic energy-producing and machine-making industries so that we can re-equip our own industry and help in the establishment of industry in backward countries. At the same time all our producer-goods industries and our agriculture need to be transformed from their nineteenth-century practical, rule-of-thumb methods, to twentieth-century scientific methods. In this way it should be possible simultaneously to raise the standard of living at home and to capitalise our greatest real natural resource, the intelligence and ability of the people of Britain. The fear that the building up of industries in backward countries will destroy the basis for our exports is both short-sighted and dangerous. If we yield to it what will happen is that the backward countries will be developed with the help of others and that by refusing to help them we will not only lose their goodwill but fail to build up our own constructive ability.

The conversion of such general directives into a practical programme of research requires the just appreciation of the relative priorities of the different sections of British industry and agriculture. As we have limited resources, the different practical problems must be tackled each with an effort proportional to the relative importance of and reasonably expected improvement in that field. Note that this is not necessarily the importance of the field alone, for the yield of a certain amount of man- or brain-power in different fields may vary enormously, either because the subject is so difficult that there

is as yet no sure way of tackling it—as in the case of many biological and medical problems—or for almost the opposite reason, that it has been so successfully tackled that it has reached the state of "diminishing returns," as in some parts of the electrical industry. The problem of finding the priorities of scientific effort to be devoted to different fields is, however, extremely difficult in practice and, unfortunately, it is the one problem that at the moment it is nobody's business to solve. Nevertheless, it will have to be solved simply because it is impossible to get along in the separate fields without running across it at every turn.

A precise determination of priorities will be possible only if we have something of the nature of a "general staff" for science which could proceed on the basis of properly carried-out surveys both in the industrial and scientific field. Even with the knowledge at present available it should, however, be possible to get out a rough programme on which work could be started without delay. The industries of Britain can be divided into five great groups: power-producing industries (coal and electricity), materials-producing industries (heavy industry), machinery-producing industries (engineering), consumption-goods industries, and services (transport and communications); if to these we add agriculture as the food-producing industry and medicine as the health-preserving industry, the major fields of human enterprise are covered.

Power-producing industry in Britain is largely a matter of the winning and utilisation of coal, which produces all but about 5 per cent of power used directly or through electricity. Up to the present an entirely negligible amount of research has been involved in coal-mining: there is not even a coal-mining research station, although as a result of public outcry there is a station which studies safety in mines. There is no doubt that here research might have revolutionary effects, particularly in the application of modern conceptions derived from oil practice, of mining not by hand, but by chemical action underground as in the great Russian development of underground gasification. That method, together with open-cut and rational mechanical cutting in transportation, may halt and reverse the decay of British coal-mining. At least as important as the winning of coal is the using of it. Though in a few modern electric plants there is real economy—even

there only 40 per cent of the energy is used—most coal, on the railways, in ships and in industry, to say nothing of the domestic fireplace, is used with far less efficiency. There can be no reasonable doubt that if we were really to drive for the full utilisation of coal, we should get two or three times the value out of our present resources.

The materials-producing industries are an amalgamation of the older industries such as brickmaking and pottery, steel-making and smelting, with the more modern chemical industry. The efficiency of the processes of the latter as against the former give hope that with good research and development all our materials-producing industries might be completely transformed, particularly from the point of view of the economic utilisation of raw materials. Coal is here used both as a means of producing heat and as a chemical reagent; in both roles it is used extremely wastefully. It is not sufficient, however, to produce materials economically, we should consider their use at least as carefully. Under the old dispensation the justification for making a material was that you could sell it; in the new, it should be that it is essential to the national economy. Most materials, particularly building materials, are used wastefully partly from tradition and partly from our lack of knowledge of their properties as a basis for rational design. The tendency here again will be towards economy: using less and getting more out of it.

The making of machines was the beginning of Britain's industrial greatness and British genius and craftsmanship have continued to find expression in engineering. Nevertheless, here again, tradition is a bad guide in two directions. Both in rational design, to fit well analysed function, and in rational production, to secure economy by standardisation and mass production, Britain has fallen behind other countries, particularly the United States. Both these aims can be achieved if they are consciously sought; skill and science here again can find economic solutions which can make up for the greater natural resources and for the larger markets of other countries. But this will not happen unless we can train a new generation of engineers who can make the fullest use of science both in design and production.

The prime consumer-goods industries are textiles, and here again Britain, once first in the field, has fallen sadly behind.

Yet the possibilities of improvement of textile qualities and methods of manufacture are, with our modern knowledge of the physical properties and chemical constitution of natural and artificial fibres, literally dazzling. The adaptability which enabled Britain in the eighteenth century to turn from the native wool staple and conquer the world with cotton can be applied again to the newer substances, if we are prepared to abandon prejudice in favour of this or that material or process and consider only the results. The same considerations hold for the other multifarous consumption goods—furniture, household equipment and the like—where the scientific study of user needs rather than smart salesmanship is the key to both the home and the foreign markets.

Transport, as the war has shown, is more a question of scientific organisation and planning that it is of merely producing faster, smarter and cheaper cars. In a small country like Britain with its haphazard street and road system and its dense population, lack of planning can actually cause increased effort on transport to result in diminished returns and bring as well a horrifying toll of accident. Modern statistical methods and operational research could, if their findings were implemented, show us how to see that the goods and passengers of our country get to their destination rapidly and without danger.

The great discoveries of this century, both in applied biology and the science of nutrition, have at last made it possible to plan the production and consumption of food in a rational way. As a result of the application of this knowledge in the war years we have managed to increase the nutritional standards, and with them the health and growth of the population at a time when our imports of food were cut down by half. The task now is to maintain and extend those methods in peace. There is no doubt that even with the discoveries already made we should be able to provide a better and more appetising diet for ourselves and find the means by which the hundreds of millions of undernourished peoples in the backward countries can produce adequate nourishment. Finally the health of present and future generations depends on a far deeper knowledge of physiology and biochemistry, which can only be obtained by a vast increase of research devoted to medicine. No amount of research can, however, lead to a tolerable condition for human beings until it is realised that we must apply it to something

better than retail peddling of relief from pain. The responsibility of a modern society is to determine the best possible physical environment for its citizens and to see that they get it.

These possibilities for human betterment, which have been no more than indicated here, are not visionary but based on practical experience of thousands of scientific workers who have participated in the co-ordinated effort of the war years. We have the ability in this country to put these changes through. Perhaps the most important political question of the next few years is whether the people of this country will have the insight and determination to get on with the job.

From *Contact*, Autumn 1945

INFORMATION SERVICE AS AN ESSENTIAL IN THE PROGRESS OF SCIENCE

THE subject of my address is primarily the user's side of library service in relation to research. The world of the scientific research worker and the world of the librarian have, in my opinion, been too far apart in the past. Librarians have striven with very good will to give the scientific research worker the best service they could but they have not had much assistance in finding out what it was that the research worker needed. At the same time the research worker has never been able to make the fullest use of the special library largely because of his ignorance of the possibilities of recent developments in library technique. Many research workers do their own library work, in an amateur way, or discover for themselves many of the techniques already long known in the library world.

The experience of the war has taught a very large number of scientists the vital function of an efficient information service. The much wider range over which research was carried out and the necessity to familiarise oneself with entirely novel subjects have put a premium on information gained from libraries rather than from slowly acquired experience and casual conversation. In the course of this we have come to

realise that the unity and complexity of science has grown to such a degree that the library and information service has become a key to conscious progress along the whole front of advancing knowledge. For it to be effective, however, it is necessary that the purpose and activity of library service should change from what might be called a negative to a positive activity. Old libraries were conceived as depositories of knowledge: the modern library should be a distributor and organiser of knowledge.

The two aims which, in my opinion, the modern information service should set itself are, first, to secure that the right information in the right form is sent to the right people and, second, to arrange that facts, of however diverse origin, which may bear on any particular topic should be correlated for the study of that topic. These may be called the DISTRIBUTIVE and INTEGRATIVE aspects of library service. They do not supersede the older function of libraries of acting as a storehouse for all recorded knowledge, available to all seekers for such knowledge, but they do supplement them. They inevitably involve a very great increase in the demands put on the library service.

The distributive function of special libraries is by no means as simple as it sounds. The factor that must increasingly be taken into account is that while the annual increment of new knowledge in the whole field of science and in any particular field is rapidly increasing, the capacity of each individual research worker, for assimilating knowledge is absolutely limited and has already in many cases reached its limit. If any research worker were to receive all the facts relevant to his work in the form in which those facts were originally put out, he would literally not have the time to read the material coming to him, much less to absorb it. Actually the position is far worse than this. At present the research worker receives in journals and books a very large number of facts that are of no use to him at all but which have to be ploughed through in order to find those which are of use, and at the same time many relevant facts never reach him in any form. Now the old escape from this state of affairs, that of specialising in ever narrowing fields in the hope of acquiring all the information available from that field, has proved both impossible and dangerous. We do not want over-specialisation; what we do want is an

information service which will avoid the temptation to unnecessary specialisation. This means putting a great deal more work into the handling of material between one research worker and another. It involves much boiling down and simplifying as well as a great deal of rearrangement and correlating of material. This is, of course, part of the second, integrative, function which I have suggested should be aimed at by the modern librarian.

Now here we touch on a fundamental difficulty. In the past it was possible, up to a point, for the librarian to handle printed matter in a somewhat mechanical way by title and catalogue number: he only needed to know enough of the matter he was handling to be able to catalogue it correctly. What I suggest is needed in the future is that the librarian should be master of the material itself, and that he be in a position to present it in forms different from those in which he receives it. Now the objection may be made that this is asking far too much —indeed, asking more of the librarian than of the research worker. The research worker is only expected to understand one subject, but the librarian all subjects. I agree that this is an impossible demand, but I do not think it is implied by the requirements I have indicated. In my opinion it is not the librarian's function himself to condense and reallocate the material he deals with; it is his function rather to organise that condensation and reallocation through the research workers themselves. In other words, it is the librarian's job, not merely to accept material as sent to him, but to demand that the material be presented in the appropriate forms for passing on. I shall later give more detailed suggestions as to how this can be done, but it is clear that it implies a very much closer relation between the librarian and the research worker than has existed in the past. It also implies, of course, a closer relation between the function of the librarian and the function of the publisher, both of periodicals and of books. In fact the whole of scientific communications between scientists and between them and the technical and lay public is one unified subject. The separation between the business of producing literature and that of storing and distributing it had been the curse of the learned world long before the printing press was invented. But what was tolerable when it was difficult for the learned man to find enough that was worth his while to read

has now become, under the enormous mass of published material, a totally intolerable position, and one whose continuance threatens the whole progress of knowledge.

A very good example of this can be seen by the experience of the war. In the field of war science the information services played an enormously important role. During the war, research was immensely speeded up and carried out on a much larger scale than had ever been conceived before. It was also involved in the serious restrictions of a complicated and graded security system. The development of information services was largely *ad hoc*, and though it never met the full requirements of the situation, it had before the end of the war reached a sufficiently advanced stage to indicate what a practical, ideal organisation should be.

The great curse of technical information in the war was departmentalism. To speak of England alone, each of the ministries—and many of the departments inside the ministries—had its own library and information service. When these proved inadequate, as they nearly always did, enterprising persons set up their own information services, often in almost complete ignorance of what already existed. An effort was made in the middle of the war to reduce this chaos, but I regret to say that it was sternly resisted by the senior librarians. The only result was in an inquiry by the Ministry of Production which revealed the following fact: that there existed no list in government offices or in any ministry of what libraries or information services were available in the ministries. Research was able to indicate the existence of some sixty of these, but this may not have been complete. There were, for example, five bodies which collected information on tanks, and none of these knew of the existence of all the others. Right to the end of the war the unfortunate technical officer had to read through the separate lists of acquisitions to the libraries of three to five ministries, all containing very largely the same papers differently catalogued and with no uniform system of reference—and, in many cases, with no indication of the contents of the papers. A paper might be, for instance, "Progress Report of the B.17 Committee," where quasi-omniscience would be required even to know what matters they referred to. That the system worked at all is somewhat of a miracle, but that it should be considered perfect is an even greater one. Yet

this was the view of many of the senior librarians who saw no reason for any change. The most senior of all expressed his view that in technical matters there was never any difficulty in obtaining the required information as long as one knew whom to ask for it! This is, of course, an extreme expression of what might be called the personal view of exchange of information which is quite adequate for a restricted society of people who all belong to the same clubs and are apt to talk shop, but even when it works it is, under modern conditions, a serious waste of brain power. It depends on the existence of a small number of people with long experience and retentive memories who are expected to spend a great proportion of their time in answering questions on matters of information which could just as easily be obtained by an even moderately efficient library service. It rather reminds one of the habits of certain tropical ants where some workers are used exclusively as a kind of living honeypots for the community.

Nevertheless in spite of these somewhat horrifying deficiencies, the work of the information services in the war ministries proved to be absolutely invaluable, particularly as military affairs required contributions from a large number of widely separated types of information. Particular success in this field was scored by the Information Service of the American Office of Scientific Research and Development and by that of the British Commonwealth Scientific Office in Washington.

In war science it was very often necessary to produce the same material in a large number of different forms suitable, for instance, for production engineers, military technicians and operational soldiers. This involved a considerable effort on the part of the scientific and records staffs employed on it, though well worth the trouble. Simplified presentation, with an eye always to the particular reader or user, often brings a good deal more out of the material than an accurate but formal scientific presentation. It was also necessary at frequent intervals to provide summaries indicating the position to date. Thus it was usually possible, without too much loss of time, to keep permanently up to date in a large number of fields simultaneously. These lessons of the war should not be lost in peacetime information services. If the army thought it worth while to set aside considerable personnel and printing facilities for this purpose, when there was an acute demand for

both, there is even stronger reason for the adequate development of the information services in peace.

When we come to consider in greater detail the type of information service required for the furthering of scientific research, it becomes apparent immediately that it is not a matter of detailed improvement of existing organisations, which may well indeed make things worse rather than better by blocking the way to more radical change. Only a thorough recasting of the whole system with the conscious aim of satisfying the two requirements mentioned at the outset, that is, a positive distribution and the conscious integration of information, will suffice. Fortunately the present period of rehabilitation after the war, the enormous gaps left by six years' interruption of science and the destruction of European and particularly German science, furnishes both the necessity and the opportunity for a new start, while the formation of new international cultural bodies such as the United Nations Educational Scientific and Cultural Organisation provides a means for carrying it out.

Any scheme for better information facilities in science must necessarily cover publication as much as library work. To arrive at such a scheme would itself require fairly detailed consultation between scientists, librarians, editors and publishers, and it is hoped that some such discussions will be organised in the near future.[1] In the meantime we can sketch out a rough plan of the type of organisation that would seem to satisfy the major requirements.

The media of scientific communications have now grown to include many printed units of different scope and function, ranging from large and quasi-permanent publications such as handbooks, through monographs, theses, papers, down to letters and notes. Parallel with these primary publications are a number of secondary ones, reviews of books, abstracts, progress reviews, reports of lectures and science news. All these have their different and fairly distinct functions and it is unlikely that we can dispense with any of them. On the other hand it will be necessary to see that they are produced in a more orderly manner so as to avoid what exists at present to an enormous degree—both duplication and gaps.

The primary unit in scientific publication is the individual scientific paper dealing comprehensively with one topic: books

[1] See Postscript, page 253.

and other larger units may be considered as an accumulation of papers, while notes and letters are papers in embryo. The organisation of publication and recording should therefore centre, in my opinion, on that of the scientific paper. It will be noticed that in the list given there is no mention of what has been in the past the most important means of scientific publication, the scientific journal. Now the journal, in my opinion, and in that of many other scientists, has ceased to be a really satisfactory means of distributing scientific information. Each number consists essentially of a number of papers which have in common only the fact that they were submitted at the same time, and little other material except occasional abstracts and reviews which ought, in my opinion, to be published elsewhere. The result of this method of publication is that scientists who take journals are presented with possibly one paper in which they are interested, together with twenty or thirty that do not concern them. At the same time, because, for reasons of economy, they cannot take all the journals affecting their own field, they are obliged to make other shifts to get the rest of their material or to go without it.

One method which has come into vogue, and itself shows the failure of the present system, is the circularising of individual reprints. This is done in the most clumsy and expensive method by the research workers themselves who are rarely able to afford to send reprints to all those who would be interested, even if they knew where they were. Another is the recourse to libraries, which, because they can hardly ever take more than one number of each journal, and because the study of a single paper requires considerable time, leads to very serious delays. Of course, photostat and microfilm methods could to a certain extent mitigate this nuisance, but no serious mitigation is possible without complete recasting.

Now such recasting is possible, and, indeed, a fairly detailed scheme for doing so has already been put forward by a group of the members of the Association of Scientific Workers, partly on the basis of suggestions put forward by Dr. N. W. Pirie.[1] They depend on the fact that the great majority of scientific journals are produced for learned societies. In many cases these societies, particularly the smaller ones, publish journals very largely because it is only in this way that they may

[1] *Journal of Documentation*, vi, 26.

obtain by exchange the journals of other societies. This results, of course, in a vast multiplicity of scientific journals of which, in 1930, there were already 33,000 more or less regularly published. (In 1948 the number was over 50,000.)

In the proposed scheme, each country would have a centre of scientific publication and exchange which would receive from societies papers already passed by referees as suitable for publication and lists of members to whom papers from any part of the world on specified subjects or groups of subjects, should be sent. The national centres would act as clearing-houses for these papers, arranging for their internal distribution and sending others in blocks in appropriate numbers to the clearing-houses in other countries for distribution to the scientists there. Payment of a subscription to one society would entitle the subscriber to the services of the whole organisation. It is not necessary, though it may very well be possible, for such a system to be economically self-supporting, but it is clear that such a unified system could make a very good claim for governmental support.

A similar service but with a much wider network could be organised for science abstracts, which would be prepared once and for all by the author and verified by his own scientific society. It might also be possible to publish a number of abstracts from papers of value to several fields of science, for distribution in such fields. All abstracts would be produced in a form suitable for modern filing systems. Similarly, the scientific societies would make themselves responsible for the production of monographs and textbooks, though leaving wide freedom for original work of an unorthodox kind.

It is clear that this scheme requires a great deal more working out, but I am convinced it is perfectly feasible, and that unless something like this is done, the literature of scientific research will be choked by its own productivity.

It is particularly important that the scheme should start from the outset on an international basis. If some countries stick to the old system, the value of the new would be very largely lost. The danger is, of course, that energetic scientists and librarians, and the more active centres of research such as the United States, Britain and the Soviet Union, feeling the excessive strain of the present totally inadequate system of information, will start on their own developing comprehensive

systems. It is also to be feared that this may happen even inside particular countries through the independent action of scientific societies. It is very much the responsibility of librarians to urge on scientific societies and governments the folly of such courses. They alone are able to appreciate the need for order and uniformity in the presentation and distribution of information.

I have said little in this address on the possibilities of the full resources of modern library technical aids such as microfilm, Hollerith or photo-electric indexing devices. This is largely because of my lack of any intimate experience of them. I am convinced, however, that they are due for an extremely rapid period of development and may, indeed, completely supersede many methods we have at present for transmitting information. In particular the transmission of visual and aural impressions of experiments by micro-cinema may make a great deal of printed matter unnecessary, while the possibilities of television may have an equally profound effect on the personal contact between scientists. We can imagine, for instance, a complex experiment carried out by four or five operators simultaneously in different parts of the world.

All these are developments for the future, but immediately before us lies the task of putting our house in order after the end of this period of destruction and preparing for the much greater demands of the new era ushered in by atomic power. Here is a task which should occupy the special librarians in conjunction with the scientists during the years of rehabilitation after the war.

From the Report of Conference, September 1945, Association of Special Libraries and Information Bureaux.

INTERNATIONAL SCIENTIFIC ORGANISATION

The Scientist as World Citizen

AS a social institution science is intrinsically international. Because the kind of knowledge that is characteristic of science is communicable and verifiable, and both of these by action as well as by word, the normal barriers of language and

government, even the barriers of religion, have done far less to prevent its diffusion than that of any other cultural form. The internationalism of science was also, from the start, a positive one. Those men we recognise as the earliest scientists, the philosophers of Ionian Greece, had acquired their science by mixing with other people, either by travelling themselves or by talking with travellers. The very birth of the scientific spirit in Greece was largely due to the internationalism in ideas and techniques that Greek traders introduced into the ancient world. The poet was recognised among people who could understand his language: the priest or the prophet in the regions where common beliefs held: but the scientist, the man of natural learning, could go everywhere, and everywhere be well received.

This early privilege of men of science was recognised tacitly practically up to our time. In the Middle Ages the bridge between the Mohammedan and Christian world was largely made by men of science. The only limitation to their movements was the embarrassing value which they had for the potentates of the time who liked to assemble and often virtually to imprison scientists so as to add to the brilliance of their courts. This freedom of movement itself provided the first organisation of science. Science was an international institution, in fact, long before it became a national one. The true scientist wished to hear every opinion that was held in the world, even if he was as likely to disagree as to agree with it. and he wanted recognition for his own. That could only be done by visiting in turn all the centres of thought: Oxford, Paris, Salerno, Toledo, sometimes even Constantinople or Damascus. The scientists of the Middle Ages were very few; it was not beyond the ability of a single man to have known personally and had discussions with every scientist of repute in his own time. Books were necessary, not so much for communication between the living, but because ideas changed so slowly that they might expect to outlast their writers by many generations. It was only with the first appearance of capitalism and the mechanical revolution in the seventeenth century that scientists became too active and too numerous for such simple methods of communication. Formal organisation had to supplement the work of the wandering scholars.

The first organisations of science in the Renaissance world

were social and local. What had before been merely a gathering of friends of learning now became an institution. But once they had acquired importance and with it the patronage of the great, they inevitably began to appear as part of the apparatus of the new nation-states that were forming. This nationalist tendency, however, was counterbalanced by the voyages and discoveries equally characteristic of the Renaissance. The objects of the early scientific societies were not only to consider the working of Nature at home, but to examine all her manifestations abroad in the marvels of the New World and in the discoveries made in foreign countries. In the formation of the Royal Society, the arts at home and commerce abroad were equally important as objects. Among the aims of the Society the interest in foreign travel and in contact with foreign scientists ranked very high.[1]

In the seventeenth and eighteenth centuries there grew up through the official setting up of scientific academies the first recognisable formal organisation of science. The academies, which were all more or less of a pattern, published proceedings which they exchanged with other academies, with an official foreign secretary through whom letters, papers and books could be exchanged. Visits between fellows of the academies were frequent and cordial.

The peculiar immunities of scientists were fully recognised even in wartime. The United States Congress, for instance, during the Wars of Independence, sent to every ship of their new navy a letter specifically exempting Captain Cook from any molestation and enjoining that assistance be given to him. The Russians were not behindhand in their hospitality to Captain Cook in Kamchatka. As for the French, we have the notable case of the reception granted to Davy and the young Faraday

[1] "And further, for the improvement of the experiments, arts and sciences of the aforesaid Royal Society . . . we have given and granted . . . to the aforesaid President, Council, and Fellows of the aforesaid Royal Society, and to their successors for ever, that they and their successors . . . may and shall have from time to time full power and authority . . . in the name of the Royal Society, to enjoy mutual intelligence and affairs with all and all manner of strangers and foreigners, whether private or collegiate, corporate or politic, without any molestation, interruption or disturbance whatsoever. Provided, nevertheless, that this our indulgence, so granted as it is aforesaid, be not extended to further use than the particular benefit and interest of the aforesaid Royal Society in matters or things philsophical, mathematical, or mechanical." (Chapter seventeen, Second Charter of the Royal Society, 1663.)

(This privilege, however, did not apply to some of the Fellows who had been invited to visit their colleagues in Moscow recently!)

in their travels through France in the middle of the Napoleonic wars.[1] There was in fact a tacit, almost explicit, agreement among all the heads of States that scientists were not to be treated as nationals but as members of an international corporation whose activities were of general benefit to all nations.

The Effects of the First World War

This admirable system never formally broke down but after the turn of the nineteenth century it began to fall into desuetude for a number of reasons. The first was, paradoxically, the rapid growth in numbers of the scientists themselves and the remarkable ease of communication that existed for almost everyone in the years of *laissez-faire*: passports and government support tended to become less and less necessary. The scientist, if he had the money, went where he wanted and saw whom he wanted with the minimum of formality. The academies, still the home of the elect, tended to become dwarfed in practical importance by the scientific societies devoted to separate sciences. *Ad hoc* meetings and conferences of these societies provided meeting-grounds in various countries in turn.

The first step towards the more formal organisation of science came, characteristically enough, from Germany in the proposal of the Royal Society of Prussia to the Royal Society of London that they should form a closer union for the interchange of scientific information and for facilitating visits. The Royal Society of London agreed if union were widened to include academies of other countries, and this was in fact the origin of the International Association of Academies. It was clear that even then towards the end of the nineteenth century a feeling was abroad that an international organisation of science of a more formal kind was really needed, and up to the outbreak of the first world war it seemed very likely that this would come about by a slow process of accretion and organisation round the International Association of Academies.

[1] Napoleon founded a prize for the best experiment on the galvanic fluid. This medal, for the year 1807, was given to Davy for his Bakerian lecture to the Royal Institution on 20th November 1806. Davy wrote to Mr. Poole: "Some people say I ought not to accept this prize, and there have been foolish paragraphs in the papers to that effect; but if the two countries or governments are at war, the men of science are not. That would indeed be a civil war of the worst description; we should rather, through the instrumentality of men of science, soften the asperities of national hostility."

The first world war, by lining up the scientists with their national states, abruptly arrested this movement. It is true that for many years previously a number of scientists had assisted the war establishments of their countries in researches which somewhat remotely tended to the development of better weapons or devices, but secrecy was not much thought of and even war scientists remained on excellent personal terms. Most of the classic researches of the early French mathematicians into ballistics were published rapidly and in full and the same was true for most of the explosives research. There was very little other war science. It was not, however, the work that the scientists did as war scientists that caused the breakdown of the first world war, but the ideological issues that were raised. The breach between the Allied and German scientists became a gulf of mistrust and mutual abuse, felt most deeply by the scientists of France and Belgium.

At the end of the war there was naturally a move to re-integrate science in line with the ideals of the League of Nations. But this effort, which resulted in the formation in 1919 of the International Research Council, fostered by a more general but even vaguer body, the Institut International pour la Coopération Intellectuelle, suffered from severe handicaps from the very start. In the first place the hangover of the war prevented for a long time the inclusion of ex-enemy scientists which, as German science had hardly been damaged at all in the war, gave the Allies anything but a monopoly of scientific activity. It took time to heal that breach, and in some sense it never was healed because the advent of the Nazis occurred before the task was completed. The other handicap was that, although there was a concept of scientific union, it was viewed in an entirely passive way. It was considered sufficient to have some organisation to facilitate scientific interchanges; any positive action could be taken individually by the scientists in the different countries. This also resulted from the failure to realise that any scientific organisation requires staff and funds on a considerable scale and that without staff and funds it becomes a name without reality.

In the early days, however, the International Council of Scientific Unions (as the International Research Council became in 1931) had helped very considerably in its strictly facultative role. It enabled those scientists who had to work

together, on account of the intrinsic nature of their science, to secure a mechanism for their collaboration, and it helped in the foundation of the vigorous unions such as those of astronomy and meteorology. Outside those fields it made extremely little impression. By the end of the twenties probably not one scientist in ten had even heard of its existence and the number who felt its benefits directly, or who had done anything to help it, was probably not more than one in a thousand.

The Effects of the Second World War

The last uneasy years before the second world war were most unfavourable to scientific organisation. Already scientific congresses were being turned into ideological battlegrounds and the shadow of military and industrial secrecy was being increasingly felt. In effect the second world war suspended all the old forms of international scientific organisation. There was, even more than in the first world war, a complete break between scientists of the Axis and those of the United Nations. The break was hardly less between the scientists of the belligerent countries and those of the few remaining neutrals. This was because in the belligerent countries there was more or less total utilisation of scientists for war purposes. Free travel became impossible other than on government business and all scientific publications were censored.

In contrast to this there grew up at the same time among the United Nations a new type of scientific organisation of a much more positive character directed towards the solution of both immediate and secondary war problems—those of health and agriculture as much as those of weapons and tactics. This area of free interchange included Britain, the United States and the Dominions, to a far less extent India and China. The Soviet Union was, unfortunately, never included in these arrangements and this omission, which could have been so easily remedied in 1941, remains as one of the greatest bars to international co-operation in science to this day. It does not seem that any corresponding organisation occurred in Axis-occupied Europe. There German science was dominant and the scientists of France and the Low Countries were very soon in tacit opposition even while the German attitude remained correct.

In the Anglo-American sphere the needs of war, after initial

delays, imposed a type of organisation which was far more efficient than anything that had been seen before. This was largely because in each country the activities of the extremely limited number of available scientists had to be used economcally and with due respect to priorities. War science had to be planned; what is more, the plans of the various allies had to be co-ordinated to avoid overlapping. This involved an exchange of information and personnel with facilities that had never existed before: virtually free transport determined only by the importance of the journey and a rationalised exchange of information which, for those engaged in war work, largely neutralised the bad results of secrecy. As all competent scientists in any field were inside the secrecy arrangements for that field, they had, in fact, a greater knowledge of what was going on than they had had in peace.

Of the particular organisations of war science that would seem to have an important bearing on the reconstruction of science after the war, perhaps the most interesting is the British Commonwealth Science Office in Washington. This office acted as a clearing-house between Britain, the Dominions, and the United States and came to be recognised as effectively the scientific clearing-house of the whole United Nations. It collected and transmitted information, filed reports and arranged for visits of experts. In this way it kept its finger on the pulse of scientific life and was able in many cases to point to inefficiencies and to see that they were remedied. The British Commonwealth Scientific Office may well furnish the prototype for that part of the international organisation that is concerned with the maintenance, by full and intelligently directed communications, of the highest possible scientific level among countries of already high scientific attainment.

The war, however, also gave other indications of what could be done in less developed countries. The scientific section of the Middle East Supply Centre was formed to deal with the multifarious problems involved in the maintenance of large bodies of United Nations troops in the Middle East under conditions where normal routes of supply had been cut by the enemy.[1] The problems that had to be faced were very largely those of application of existing knowledge rather than research.

[1] Those who have seen the film *Today and Tomorrow* will get some idea of the internal work of the Middle East Supply Centre.

They were problems of disease control, agricultural activity and the creation of new industries. In all of these notable progress was made, enlisting for the most part native scientific talent. Naturally there was no time for extended courses of training, but it was remarkable how rapidly quite complicated techniques could be learned by untrained and often illiterate peasants and craftsmen. The other aspect of its work was the assessment of the common problems of whole regions characterised by certain natural features, in this case aridity modified by irrigation. It is clear from its work that the problems of raising the standards of living throughout the world would be very much eased if these problems could be treated in common over a wide natural region, i.e. problems of the Arctic North, whether in Canada or the U.S.S.R.; problems of the wet tropics, whether in Africa, South America or New Guinea, etc.

As a further example of wartime science triumphing over difficulties should be mentioned the work of the Sino-British Scientific Co-operation Office at Chungking directed by Dr. Joseph Needham. Here, every document or piece of equipment had to fight its way for priority among the trickle of goods flown over the "Hump." Nevertheless, on this meagre ration Needham was able to supply the Chinese scientists with key pieces of information which helped them to rebuild their war and peace industries, to equip their armies, to grow more food and to protect themselves against disease. It was this experience that made Needham realise how much could be done with how little in the remote parts of the world and to plead eloquently, and in the end successfully, for the inclusion of science among the tasks of the United Nations Educational, Scientific and Cultural Organisation. Taken in all, wartime experience has given us the most useful indications and, indeed, experimental trials, of the type of organisation which the post-war world will need.

Basic Reasons for a World Organisation

It is perhaps not generally recognised how unevenly distributed modern science is in the world. Scientific work originates in fundamental research which is carried out in laboratories usually associated with universities or, more rarely, with specially founded institutes. At the present time we have no

survey of the distribution of these owing to the upsets of the war, but it would be safe to venture that some ninety per cent of them are to be found associated with the highly undustrialised areas of the world—in the United States, Britain, the Soviet Union, France and the smaller European countries—and that in the great bulk of Asia, Africa and South America little science is taught and still less originates.

The first task of a world scientific organisation is to even out this inequality. There are a number of imperative reasons for this. In the first place the supply of really original science is strictly limited by the number of people capable of producing it. At present it is undoubtedly true that the opportunities for scientific advance are far greater than the number of people at present trained and competent to make use of them. It is therefore essential that we should exploit to the full the available human potential of intelligence. This can be done and should be done both by the more effective use of the human potential in the highly developed countries and to an even greater extent by the tapping of the untouched reserves that exist in the more undeveloped and populous countries in the rest of the world. The individual achievements of the scientists of China and India have shown what is possible. What is now necessary is to multiply these achievements. There is another more cogent, short-term reason, however: at the present moment, largely, but by no means entirely, on account of the war, there is an acute crisis in the very means of existence over two-thirds of the inhabited world. Food is lacking, health is poor, human efficiency is low and a rapid rise in population tends to exacerbate all these features. The only possible means by which man can escape from this increasingly desperate tragedy is by an intense and immediate application of scientific techniques. But these techniques must be applied to a large extent by the people themselves and what the more fortunate industrial countries can do is to supply a certain amount of productive equipment and a certain amount of technical advice. Relief in kind is but a temporary palliative.

Before coming to a discussion of the actual proposals for the organisation of science in the post-war world which are being made in connection with UNESCO, it is worth while considering what in general are the needs for specifically international organisation in science. The tendencies which have

existed now for some decades are pointing to a common pattern for the organisation of science inside modern national states or federations. In all nations with advanced industrial structures, scientific activities are carried out in three types of organisation: in university laboratories or independent institutions, in government laboratories and in industrial laboratories. The tendency is for fundamental science to be limited to the first category and strictly applied science to the last, with government science bridging between them and overlapping both. During the war, progress in this direction has gone further and tended towards a general governmental supervision of all scientific activities, limiting itself in the case of academic science to the provision of funds for the carrying out of certain very loosely specified objectives, but in the case of applied research exerting a much more detailed control in the national interest. Such an arrangement has long been in force in the Soviet Union, while the proposals in the Bush report in the United States and the appointment of a corresponding committee to review the organisation of science in Britain point unmistakably to steps being taken in this direction in all important industrial countries.

Now, to encourage a closer integration in the organisation of national science without a corresponding effort to organise international science would lead to aggravation of that tendency to split science on national lines which was already in evidence before the war. As long as national science remains completely unorganised or organised entirely through independent scientific societies, it is possible, and indeed likely, that scientific workers in any particular field in one country may be in closer touch with the workers in that field in another country than they are with scientists in a different field in their own country. This contact becomes increasingly difficult to maintain without assistance the more scientists are orientated towards their own country.

National scientific organisation possesses a deceptive completeness. In any large country, such as Great Britain with its colonial dependencies, there is a sufficient range of industrial activity and variety of natural conditions to provide work for scientists in every field of research. It is fairly obvious that there are far more active scientists in Britain alone today than there were scientists in the whole world fifty years ago. National

science can be made to work, and to work well, within such boundaries. It is, however, a deceptive completeness because the rate of advance inside the national pool is bound to be very much less than if the pool were enlarged to cover the activities of scientists in other countries. Whether there is planning or not, it is inevitable that the paths of discovery in different countries will be, to a certain extent, complementary. If the sciences in the various countries are not in contact, there will be waste of effort in following the same tracks. Far worse, however, will be the effect of the existence in each country of pieces of information, possibly of little value singly, which, if combined, would give rise to discoveries of wide-reaching importance. Anyone who has had the experience of scientific travel will recognise how easy it is to pick up missing clues in one's own work, and to find that very often they are not appreciated as of any importance in the laboratories where they are found because of lack of information on what has been done elsewhere.

But even this is probably not the main bad result of the enclosure of science in national boundaries. The rate of advance of science depends very largely not on the accumulation, or even the interchange, of pieces of knowledge, but on the active interplay of minds in personal discussion and argument, or in actual collaboration in tackling a problem. The wider the freedom of choice of critics and collaborators, the livelier this interchange, the more rapidly will science progress. The rate of advance of science as a whole, and with it the rate of advance of science in any particular country, will be absolutely slowed down to a small fraction of its possible rate by the absence of effective international communication.

The danger may even go further, and bring some, or all, of science to a standstill. It is becoming recognised that a certain minimum of activity is required in any science, or in all the sciences, to permit of significant new advances. Scientific activity is notoriously inconstant; it flames up for a certain time in one country, and then dies down again, and is generally only revived by a new influence coming from another centre. It may easily happen, in the absence of scientific organisation, that certain sciences—or perhaps all the sciences—in a country may lose their spontaneity: that that country may fall behind the rest of the world in its scientific culture. It may then

stagnate and become mere repetitive dogma and ultimately die. Such things have happened in history before, notably, of course, in the decay of science in the Roman Empire, and again in the Islamic world after the fourteenth century. Only an active and world-wide scientific interchange can provide any guarantee against its recurrence.

The foregoing remarks apply principally to fundamental science, but corresponding and equally serious dangers threaten applied science. Where fundamental science is not active, there is a very strong tendency to rely, in practice, on formulae and so produce an atmosphere in which real technical innovation is hampered by traditional attachment to past methods. Once a race of imaginative and enterprising engineers is allowed to die out, it is very difficult to re-create it, and there is a temptation to depend for innovations on ready-made importations from abroad which seem to the capitalists concerned a way of making money without going to the trouble and expense of thinking. The technical and ultimately the economic and political subjugation of such a country is certain. If this process goes on for a while, sciences and technology will decay in the poorer countries and be concentrated almost entirely in one or two imperial centres to the great detriment, not only of the science and technology in the rest of the world, but of that in the metropolitan countries themselves.

The danger of concentration of science in one cultural centre, even under the best conditions, is that of stifling intelligent criticism, and thus subtly endangering the essential feature by which scientific knowledge differs from conventional knowledge in the social field, such as law. It is notoriously easier to be critical of foreign ways than of one's own ways of doing things. If there are no foreigners to do this, ideas tend to become fixed, and form a barrier increasingly impenetrable to novelty. The whole history of science shows that the difficulties in the face of new discoveries are not so much the difficulties of penetrating the secrets of nature as those of overcoming traditional explanations which are often unconsciously held, and which can only be shaken when approached by people holding very different traditions.

All these are cogent arguments for the extending and increasing of international scientific activity, but it may well be said that in themselves they do not furnish an argument

for the *organisation* of such activity. Why should we not revert to the conditions of the nineteenth or eighteenth centuries, and allow the natural curiosity of the scientist and his love for travel, together with the normal channels of information, to effect all international interchange? There are three main reasons why it is not possible to turn the clock back in this way. The most important of these is that the very growth of science and of its national organisation makes the task of unaided private enterprise in this field too much for any individual human ability. Merely to find out what workers there are in one subject in different countries, and what work they are doing, is usually, with the numbers involved, an impossible task for an individual. Almost inevitably he will be limited to chance personal contacts, and miss most of what is really relevant. The day of the wandering scholar is over. A comprehensive grasp of what is going on in science, which is the only safe basis for individual advance in any part of it, can only be obtained if a certain amount of effort is put into organised presentation of the work in hand and plans for future work. The more science advances, the larger it becomes, the more is the danger that the problem of knowing what is going on will become beyond individual human capacity. It will tend to take up too much time, and even then the knowledge will be incomplete. The only way out of such an impasse is by organisation. Naturally, the form of that organisation, and how to prevent it in itself becoming a barrier to originality, is a problem that must be faced and solved, but it is not one that can be safely evaded.

The other reasons, though less fundamental, are more immediate. In the post-war world, and for some years to come, it would be idle to hope that the independent individual will have either the facilities or the permission to wander at will. Interchange of professors and students, transference of materials and publications, will require the assistance of the machinery of state. Up to now, except for the extreme urgencies of war, states have not been forthcoming in their assistance to international science, nor will they become so unless there is some organisation which is seen to be of mutual benefit to them. Finally, there is a reason, already touched on, whose appeal cannot be ignored: the very uneven state of development of science in the world, and its exacerbation by the events of the

war. Only organisation can restore science in devastated countries and raise its level in the backward ones.

Scientists and UNESCO

These reasons, and others besides, have been in the minds of men of science in many countries who have made consistent and so far fairly successful efforts to build up an effective international organisation in the world through the medium of the United Nations Organisation. This work started during the war itself. The conference of Educational Ministers in London, involving Great Britain and most of the countries under enemy occupation, laid the foundation during the war for the organisation that is now known as the United Nations Educational, Scientific and Cultural Organisation. The original conception naturally laid a very strong emphasis on educational and cultural aspects, and particularly on the extremely urgent problems that would have to be faced in their restoration in the occupied countries. From the start, however, the conference of Educational Ministers had a scientific commission of whom the late Dr. E. A. Armstrong was Chairman and J. G. Crowther the Secretary. Through their efforts, and also through those of Dr. Needham, the importance of the inclusion of science explicitly in the title of the organisation, and of the need for a strong science section, was successfully urged.

The objects of the scientific section of UNESCO fall naturally into four main groups, apart from the first or general objective of promoting international scientific co-operation in all its aspects which covers all the others. These are respectively the strengthening of international organisational links, arrangements to assist administratively and materially in the interchange of scientific knowledge and personnel, the restoration of the scientific world after the war, and assistance to national governments and United Nations organisations on topics involving science. The first three of these groups are clearly functions which only an international body of the type of UNESCO could satisfactorily carry out. The last is more a matter of convenience than principle; it is obviously useful to have a central body associated with the many United Nations organisations to which scientific problems could be referred, but its function in

this respect would be to indicate where experts could be found rather than to carry out work inside UNESCO.

It will be seen that the general tenor of these proposals is that of an essentially positive and active organisation, in this way going much further than the Institut International pour la Coopération Intellectuelle set up after the first world war. It will not, however, attempt to carry out this work alone and without regard to existing organisations. Already it is agreed in the provisional Charter of UNESCO that it should work in, and through, the existing international scientific unions. In particular, it should help to make those unions practically effective by providing them with sufficient funds and secretarial assistance. It is a sad fact, for example, that the activities of the International Council of Scientific Unions was never very great, as it possessed only an honorary secretary and not even one typist. It is clear that to be effective it will need not only a scientific commission with an adequate secretariat, but a number of branches strategically situated throughout the world, preferably one in each of the natural and cultural regions which can serve to bring to the problems of that region the collective scientific knowledge and ability of the rest of the world.[1]

The Need for Active Support by Scientists

If these problems are to be solved in practice, a purely formal organisation, however efficient, will not suffice. The active and corporate assistance of scientists will also be needed. It is proposed, in the provisional constitution of UNESCO, that in each country there should be set up a National Commission serving to focus the interest of scientists in that country on to the tasks of UNESCO. The form of these National Commissions is left for the individual countries to determine. So far, in Britain, no definite scheme has been put forward. It will almost certainly have to wait on the report of the Privy Council Committee on the organisation of science.[2] Tentative proposals, however, have been put forward in the United States. There it is proposed that the Commission should consist of a perma-

[1] A beginning has been made in the setting up at the Mexico City Congress of UNESCO in November 1947 of Field Co-operative Officers in the Middle East, Far East and Latin America.

[2] National Committees have now been set up in the Natural and Social Sciences with wide representation from different branches of science.

nent council composed of eminent scientists nominated by the State Department, and an annual congress representing all scientific societies in the country. This annual congress would have no executive function, but would serve to guide the general policy of the council for the ensuing year.

Something similar might work in this country. We suffer from not having any body that is adequately representative of all the branches, and at the same time all the grades, of scientific workers. The Royal Society does not cover the social sciences, nor does it adequately represent the younger working scientist, and each of the other scientific societies naturally only covers one part of the field. A representative body of all societies would have certain inherent disadvantages in that the representatives would have definitely to consider in the first place the interest of their societies, and only in the second place the interest of science as a whole. Perhaps the best and most democratic solution would be direct election of scientists by the whole body of scientific workers as represented in the National Register.

These, however, are questions for the future. The immediate tasks are to get UNESCO working, and to set the wheels of international scientific collaboration turning once again. It should be clear that however much governments are interested in these questions, the real drive to secure a positive programme must come from scientists themselves, and that in this they must act in an organised way. For that reason, if for no other, we need in addition to an official body such as UNESCO some body that will express on an international plane the aspirations of the scientific wokers of the world. During the war there has been a very marked growth in national bodies representing scientific workers as such, rather than as chemists, physicists, biologists, etc. In Britain, the Association of Scientific Workers increased its membership from 1,300 in August 1939 to 15,600 in December 1945.[1] New organisations of scientific workers have been formed in China and France; those in Canada, Australia, New Zealand and South Africa had already been formed before the war began.

Representatives of these and other organisations met together in July 1946 to form the World Federation of Scientific Workers (W.F.S.W.). The aims of the Federation are those of promo-

[1] Membership at the end of 1947 was 18,500.

ting the fullest utilisation of science and the greatest degree of effective co-operation between scientists in all parts of the world. To achieve this end it aims, through its constituent organisations, to improve the organisation of science on a national and international basis, and the professional, social and economic status of scientific workers throughout the world both in the natural and social sciences.

It will be seen that in many ways this reproduces the objects of UNESCO, but there is here no question of overlapping. The World Federation of Scientific Workers (W.F.S.W.), will act essentially as a co-ordinating body for the activities of the different national sections and their members, in turn, will both encourage and work for the objects of UNESCO as well as the more specifically national problems in their own country. They will furnish the rank and file of the international scientific movement.

Obstacles and Problems

With this evidence of the desire for action and consciousness of the need for its co-ordination, it would appear that the prospects of effective and beneficent scientific international organisation are bright. But none of those supporting it have overlooked the real obstacles that have to be overcome in achieving these aims. There is, in the first place, the enormous confusion and multiplicity of effort that has characterised scientific activity in the past. Many of the older scientists have yet to be convinced of the value of any organisation at all! It will also be difficult to persuade governments to accept a really effective internationalism on the part of their scientists. Only too often in the past, particularly the recent past, have governments tended to treat their scientists as virtual serfs, to prevent their movement, and to imprison them for revealing scientific information. This situation has been largely created as a result of the failure to share war secrets with all our allies during the war and, of course, particularly by the development of the atomic bomb. One of the tasks of the scientists will be to see that by international action through the United Nations the purpose of the Atomic Energy Commission is carried out, particularly its declared first purpose, the provision for exchange of scientific information. But, in view of the difficulties of the

present international situation, it is clear that the scientists throughout the world, as the scientists of America, and to a certain extent the scientists of Britain, have done already, will need to get together and to fight hard to effect this aim.

Less serious, though far more extensive, are the obstacles that will be presented by industrial secrecy and the patents system. This is a growing danger. The more scientific man-power and equipment is involved in industrial laboratories, the larger the proportion of science that is withheld from the general store of knowledge. In the past, the items thus with-held were usually the last stages of application, and had little intrinsic scientific importance. That is no longer the case. Physical principles and chemical formulae, the knowledge of which would be immediately useful to the fundamental sciences, are deliberately withheld and, what is worse, scientists employed in such enterprises are effectively prevented from frank discussion with each other over a whole range of topics, not only those covered by the secrets, but those which might lead to their discovery. The breakdown of industrial secrecy in science is actually in the interests of industry as a whole, but to get this point of view accepted by the present directors of industry is going to be a hard and long fight. It can only be won by common international action because, in a very large number of cases, the secrets belong to monopoly groups centred in particular countries, whereas the potential beneficiaries from the knowledge would be found throughout the world.

Another great task that lies before scientists of the world, and which will need their united efforts to overcome, is a more domestic one: the effective organisation of scientific information services among themselves and to the rest of the world. This is very much more than the mere organisation of scientific publication and the arrangements for visits. It should envisage the use of all present and future media of communication—film, radio, television, electron devices—on one side, and a complete but organised freedom of movement of scientific personnel on the other. The old idea that a research organisation consists of a group of scientists working in one building will have to give way to one where the same people may be occupied in laboratories and field stations scattered all over the world but in constant, day-to-day touch with one another.

It is a curious commentary on the limited practical achievements of scientists in their own interest that the very people who provide all the new methods of presentation and communication have allowed them to be used almost exclusively for purposes of war or entertainment, and have not even reserved for themselves the minimum needed to carry out their own functions. The obstacles here are not mainly financial, but depend on the fact that the great majority of scientists like getting on with the job and cannot be bothered with matters which seem to them to be purely administrative. These are left often to people who have sacrificed their own scientific careers to follow a dull and unrewarding routine which comes to be regarded as an end in itself. Thus there arises a peculiar vested interest in scientific institutions, in laboratories, societies and publications already in existence. No one so far has dared to make a frontal attack on these vested interests, and progress has been secured by working round them, creating new laboratories, societies and publications, which naturally results in even greater confusion than existed before. New possibilities opened by international organisation of science should make it possible to clean the Augean stables of science itself, and it is to be hoped that enough scientists will be found in all countries with sufficient vigour and public spirit to see that this is done.

The reorganisation of science in the international sphere can only be carried out if it has behind it both the intelligently directed drive of the scientists, who alone appreciate the complexities of the situation, and the support of the people as a whole. UNESCO will be a success if the governments who support it do so in response to vocal popular demands. Now these demands will only come if the people understand in broad terms what a vigorous, positive international science would mean for their lives, and why the securing of it quickly is a matter of high priority. In certain countries, notably in the Soviet Union, and to a certain extent in all countries, people appreciate, more than perhaps governments realise, how practically important science is to them. The events of the last few years have shown both positively and negatively how much more rapid are the effects of the science of today as compared with that of twenty years ago. D.D.T. and penicillin on the one hand, and the atomic bomb on the other, show that, in a matter of a year or two, whole ranges of human experience and

human potential for good or bad can be transformed. What is not so generally recognised, and what needs to be recognised, is that the extent of the benefits, and the assurance that they will be unalloyed benefits and not involve accompanying misfortunes such as unemployment and destruction of amenities or of life itself, depend on scientific efforts being co-ordinated internationally as well as nationally.

The scientists of the world have already a common language: they have a common purpose. They know each other personally, and through their work, more than any comparative body of people in the world. They therefore form an essential element in the creation of world unity and world peace. How effective the scientists can be for this purpose will depend very largely on the existence of a live and growing international scientific organisation.

From *Pilot Papers*, July 1946

POSTSCRIPT, JANUARY 1949

The consolidation of International Science has advanced further since this article was written. The scientific section of UNESCO has strengthened the International Scientific Unions and enabled new unions such as that for Crystallography to be formed. It has also taken the first effective steps to rationalise international literature in the field of medical abstracts.

The most important step in scientific communication was that taken by the Royal Society which held a Scientific Information Conference in June 1948. This conference though it was confined to Commonwealth countries—with U.S. observers—not only explored all aspects of scientific information—Papers, Abstracts, Indices, Reviews—but set up a permanent organisation to see that its recommendations are followed up. (See *Report of Conference*, Royal Society, 1948.)

Finally the World Federation of Scientific Workers was formally established at its first Congress in Prague in September 1948. This congress, at which thirteen national organisations were present, adopted a constitution and put forward a "Charter for Scientific Workers." (See *Nature*, clxii, p. 644, 23rd October 1948.)

why the problem of the Tennessee Valley could be defined so accurately is on account of the many, many years of neglect and disaster that preceded the setting up of the Tennessee Valley Authority.

In conditions of war we have not got that leisure to discover what our problems are. Disaster comes too rapidly in war-time, and the job is to anticipate disaster rather than to react after it. For that it is necessary to supplement existing methods of determining what the problems are by scientific means. It is necessary, in the first place, to make a scientific survey of the field of needs and to make that survey rapidly and effectively. The experience of this war has already shown that that is quite possible and can be successfully carried through. We have given to us, very largely through commercial developments but also through the development of scientific agriculture, new methods of statistical analysis and sampling that enable us to find out to any degree of accuracy required, and in as short a time as we have at our disposal, enough information on which to base action.

In the past government statistics have been thought of rather as historical data. By an exhaustive enumeration as in a census the facts of the situation are recorded for the benefit of posterity. But there are now far more rapid ways of doing this, and we can tell roughly what the situation is within a week so that action can be carried out in the week following. It is true that we have not got accuracy to seven figures, but without a snap survey action has to be taken with no figures at all, and even one figure arrived at roughly marks an enormous improvement, mathematically an infinite gain. We are able to survey the situation now in this way and to determine from such a survey what the problems really are.

The discovery and determination of the limits of current problems is a most important new function of science. When those problems are sorted out it will generally be found that most of them have in principle been solved somewhere else or by someone else, and it is a matter of getting in touch with the right people to indicate how to apply the solution to the particular case. There is a serious gap here in the failure of most of our information services to keep people in touch with existing knowledge. Modern methods of documentation, however, such as all the devices of filing, sorting and the microfilm,

are providing new means of making information instantly available to people who want it, and, going beyond that, giving people the information they ought to have before they even knew that it existed or that they wanted it. This is a positive service of information which has arisen out of the work of the librarians during the years before the war, and it is going to be one of the most important features in building up a new world.

But, obviously, all the problems will not have been already solved. There will be many that will be new, and will have to be worked out by straightforward research methods, and this is the function of the research departments. Lord Samuel and Professor Hill[1] have said something of the range of problems they cover in wartime. I should go further than that, and say that we still need, and will need very much more for the new world, a much greater organisation and collaboration between research departments. This is not only because there are far more problems than we have facilities to deal with, but because there is one feature that possibly has not been sufficiently recognised in the past, and that is that there are two entirely different sets into which researches fit. These are the set of the research users and the set of the research producers. Any large administrative body will require research coming from many different sources, and any research body, such as an institute for research in metals, for example, will be giving information to many completely diverse departments of state. Where we have lacked co-ordination in the past is in linking those two together, and for this we require a much more thorough and a much more flexible research organisation.

From the question of research we can pass to one which is not new but again requires great improvement and a new attitude, and that is development. It was calculated in an American report some years ago that the average period between the first appearance of an idea in an explicit form in the human mind and its incorporation in an article or process of common use averaged 150 years. That period has been considerably shortened, but most practical people will still tell us that it is something in the neighbourhood of ten years. In my opinion that period is too long by a factor of between 5 and 10, and the reason is that we have not attempted to get a

[1] Professor A. V. Hill, F.R.S., Report of British Association Conference, "Science and the World Order," *Advancement of Science*, No. 5, 1941.

rational drive into development. The 150-year periods were largely spent in waiting for people with specific needs or money to finance the development. To take a simple example of recent times, the zipp fastener existed in a complete form for fifteen years before anyone could be got to take it up.

Another kind of lag is due to the isolated way in which development is carried on and to its separation from research. Development and research can now be united; this is being done more and more extensively in government and war laboratories, so that the process of getting from the laboratory into the field or workshop can be immensely shortened by close co-operation between the laboratory scientists, the developmental planners, the production engineers, and the actual manufacturers and workpeople. We need the extensive use of factory research stations and experimental factories as Dr. Labarthe[1] has pointed out. In this way invention and production can be integrated and pushed forward much more rapidly.

But when we have got new implements and weapons we shall still have only just begun the problem of full utilisation of products. We have to learn how to use them to best effect. The new advantages of science are going to be very much more in the use of things even than in their production. I will not dwell on the importance of operational research, which has been adequately dealt with by Professor Hill[2], but I would say this, that operational research is not confined to wartime operations, but is just as important in every form of peacetime development. In health, in nutrition, in agriculture, everything has to be watched in the field by competent scientists, new problems discovered as they occur, and new remedies found for them at the same time. The integration between operational research and development has to be made complete. This means, in effect, that the executive function of administration has also to be scientific. Somehow the executive and the scientist have to be combined in one person or in a closely acting group.

Finally, we have the question of control. We want to see not only whether the measures taken have been successful in their

[1] Dr. A. Labarthe, Report of British Association Conference, "Science and the World Order," *Advancement of Science*, No. 5, 1941.
[2] Professor A. V. Hill, F.R.S., ibid.

original intention, but also whether they have other effects not foreseen or thought of when they were introduced. We want a permanent technically qualified body to examine what has been the result of all measures in government administration during past years and to pick out the difficulties and the new possibilities that arise out of them. With such an integrated body of information, research, development, execution and control we have the backbone of a scientific administration, one which is scientific through and through and not merely by the addition of a few eminent scientists; and we shall need that for building the world of the future.

Now it must not be imagined that anyone supposes that a general scheme of this sort will automatically and by itself transform our present administrative system. The functions mentioned are in the first place abstract and formal; to be effective they must be used intelligently by men capable at the same time of scientific understanding and responsible decision. There is no short cut which can avoid reliance in the last resort on the human element. But—and this is the important point—the ablest administrator, lacking these aids, will in the modern world be both blind and powerless. It is no longer optional whether to do things in the new or the old way. Any nation that does not work scientifically throughout will certainly go under. Militarily, economically and politically, many have already done so.[1] Nor is it sufficient for separate departments of state to be run in this way, unless similar methods are used for the wider integration of all governmental and economic activities. It should be apparent from what has already been written that a general plan, scientifically conceived and executed, is also a necessity. The existence of a general plan has passed out of the realm of controversy into that of accepted expediency. War has brought home to all nations what was apparent in peace in the Soviet Union, that a modern industrial state can only develop if its activities are co-ordinated in a common direction. On the other hand the classical economists had always maintained that planning on a large scale was dangerous, because of the possibilities of immense errors in the distribution of resources, and the absence of automatic checks on profits and loss. Their criticism, however, does not apply to planning as such, but only to unscientific planning. In this age

[1] Professor A. V. Hill, F.R.S., ibid.

it should be just as possible to plan scientifically to satisfy the immediate and future needs of a community as it is to plan for an individual large firm or department of state. In fact, comprehensive planning should be easier, because the planners do not need to take into account the variations in conditions due to actions taken in other sections. Nevertheless, planning is an immense task, which will occupy the best human abilities for many years to come; and it must be carried out scientifically. We cannot afford any longer to accept the use of science in detailed and sectional activities, and to refuse it in the general ones. Anarchy or stupidity at the centre have already served to destroy entirely the good effects of detailed excellences in different sections of industry and administration.

It is high time that the best arrangements of the central co-ordinating functions of a modern society should be considered as the most important of the scientific problems that need immediate answers. The solutions could be found in the same way as has been indicated for separate departments. The problems will be of a higher grade, however, in that they will include as component parts the possible solutions reached on the departmental level. Essentially, the problem of planning demands the solution of an equation with many variables representing different ways of expending human effort so as to give the maximum human opportunity for action and the best biological and sociological environment for humanity.

There is one aspect of general planning that interests us particularly here, *the planning of science itself*. This used to be a controversial question, but already controversy is fading away before necessities of circumstances, which will remain as great in peace as they were in war. There is, however, a very real problem in the planning of science, greater in some ways than for any other field of human activity. People cannot be ordered to think. If science is planned, it must be on an essentially voluntary and co-operative basis, under the effective control of scientists themselves. There should be no overwhelming difficulty in doing this, now that such a planning has been largely achieved for war purposes in most of the countries of the world, and for peace purposes as well in the Soviet Union.

The full utilisation of human intellectual resources can be achieved by building up a flexible organisation with an explicit

guarantee of freedom and support for the individual and with encouragement of initiative. But it cannot be too strongly emphasised that an effective planning of science implies a working plan outside science, to which the scientists can give their unqualified allegiance.

The great tragedy of the present day is that science is being used for absolutely destructive purposes, because it is organised and controlled by forces whose very existence is a negation of everything that science stands for. The fate of the German scientists is a warning to us not to accept the once prevalent view that science was concerned merely with means, and not ends. It is very largely the self-imposed limitation of the scientists' viewpoint that has made this possible. From the more general scientific point of view, there is no such thing as separating means from ends. There is one common end—*the maximum utilisation of inherent social and individual human capacities, and the necessary condition for this is the providing for all men of the best physiological and social environment.* Unless all scientists and all non-scientists alike are working for this end, men will always be in conflict with each other and will use their knowledge and ability to negate mutually what each strives for individually. The task of science cannot be separated from the task of humanity as a whole.

After this war, this will be just as true as during it. We must find a common purpose and a new motive which will transcend all the limited motives of private profit or individual security that have dominated men in the past. That motive is already abroad. It is the accepted basis of the heroically struggling Soviet Union, and it is the increasingly widespread feeling in the minds of millions in the major countries of the world, and even, however much suppressed, in the fascist countries themselves. The very existence of the present congress is proof of its increasing vitality and consciousness.

What we shall need for the new world is a full use of world resources in the service of all men. These resources, we see, are no longer material goods, coal-mines, or wheat-fields; they are far more the internal human and social resources—the resources of ordered intelligence, which is science, and which can teach men how to achieve on an ever increasing scale complete mastery over their environment; and the resources of human goodwill embodied in a well ordered social system which can

ensure that such mastery is achieved with all speed, and for the common good. But science and human goodwill cannot march separately; they must go together if they are to escape the futility and destruction of the present day. For this, science must cease to be the preserve of a few people. As the scientist comes more and more to interest himself in all human problems, so must the citizen learn a wider and deeper application of science. If the problem of organisation is the immediate one, the problem of education is in the longer run equally important. The modern state cannot hope to make use of science unless it has a scientifically educated people; and that education demands a new conception of science teaching. It must relate the achievements of science at every stage of development to the satisfaction of human needs as well as stressing, as before, its inherent experimental and logical basis.

We have come to a stage where we can hope that at last men can be conscious of the working of the society in which they live. They need that consciousness to avoid being crushed by the society they had unconsciously developed.

One aspect of this new consciousness is the transformation of state machinery from a tradition-ridden bureaucracy, permanently at loggerheads with an acquisitive industry, into an orderly and scientific organisation for satisfying human needs. I am under no illusion that the transformation can be an easy or painless one, but the very urgency of the situation which makes the change imperative for survival removes at the same time many obstacles that would have seemed insuperable in the past; and we may still hope to see the change carried out effectively before it is too late.

From the Journal of the British Association, *The Advancement of Science*, No. 5, 1941.

BRITISH INDUSTRY AND SCIENCE

ONLY through a new industrial revolution can Britain achieve an expansive economy in a modern world. This revolution is nothing more nor less than substitution of scientific for rule-of-thumb methods in production. It is not something untried

or attainable only in the future; it is already well on its way to completion both in the United States and the Soviet Union, but Britain still lags sadly behind.

What is the situation of Great Britain in the world which will take shape after the defeat of the Axis powers? Our most obvious disadvantage, the shortage of natural resources and manpower, is not the most important. Far greater is the inefficient use which we make of both of these. Our productivity per man employed in practically every industry is smaller (usually one-half to one-third) than that in the United States. It still exceeds that of the Soviet Union, but the margin is rapidly closing up; for the rate of increase of productivity in the U.S.S.R. is much greater than in this country. The immediate reason for low productivity is antiquated, under-capitalised and badly planned industry. We are unable to make use of the full economies of mass production and mechanisation. We carry the burden of a very large number of small and effectively obsolete plants which dictate the price of the product to the users, allowing a parasitic profit to the more modern plants, whose owners are relieved of the obligation to strive for lower costs and larger sales. Restriction and obstruction are the rule rather than the exception. British industry is largely monopolised or cartelised at a level which perpetuates technical inefficiency and out-of-date methods.

Britain has been longer in the field of production than any other country: this is in part the reason for its technical backwardness. But the fact that capitalism is more decadent in Britain brings an additional disadvantage. The workers of Britain are no longer prepared to accept the free-enterprise conditions involving heavy if temporary unemployment which were the rule in the United States, at least until the last depression; they are not prepared to accept, without violent protest, ruthless scrapping and rationalisation of inefficient industry, as long as the profits go into private pockets, nor are the capitalists prepared to pay the high wages that to a large extent compensate for this in the United States. The result is a mutual acquiescence in a low standard of productivity and a latent threat to resist any improvements. The case of the coal-mines is a glaring example. There we have an uneasy armistice in which the owners are only prepared to improve their efficiency if they are allowed a complete monopoly at

the expense of the consumer without government interference, while the men will not collaborate in such improvement unless there is effective nationalisation.

As long as this condition lasts, the cumulative effect will be to keep the cost of British goods above a saleable level in the free competition of world markets. This may be masked for a while by the immediate demands of post-war reconstruction, but sooner or later the result will be a further falling off in sales and a resultant depression in the standard of living. The hope of some employers that, by lowering wages through threat of unemployment, they may still be able to compete, is illusory. By then the new industrial revolution in advanced countries will make our goods unsaleable even if wages are cut to bare subsistence. If we do not put our house in order, Britain will rapidly cease to be a large-scale manufacturing or trading country, and will revert to an agricultural and petty manufacturing economy with all that this implies in drastic lowering of standards of living in our overcrowded island.

Need this happen? What actual possibilities exist for transforming British industry and agriculture to meet modern standards? The answer has already been given in principle by the war itself. The war has taught us two things; first, that it is possible, by using our resources more economically and more intelligently to increase production even with a much smaller labour force; and secondly, that as long as this is being plainly done for the interests of the people, we can get the active and enthusiastic collaboration of the workers. Technology can be improved; the efficiency of the inferior plants can be raised to that of the better units. We have already found, among technologists and workers, the men and the women who are capable of developing and controlling this transformation. If—but only if—the psychological and social conditions which the war has brought about can be retained for peace, we can hope to put through the new industrial revolution in Britain before it is too late.

The keynote of the new industrial revolution is scientific integration. Science has, of course, for many years been part of industry, and some of our more important industries, such as the electrical and chemical industries, are entirely or almost entirely based on science. Nevertheless, until recently the position of science in industry was a limited one. Science was

involved mainly in discovering new principles or new substances which could then be put to practical use by the methods evolved in traditional industry and controlled by purely monetary considerations. The organisation of the workshops, the collection of raw materials, the disposal of the product—these were "trade and industry," not science. What is happening now is that modern industry is becoming scientific through and through. This does not mean that the other qualities of engineering, design or commercial judgment are neglected, but that they are integrated in the fulfilling of a function that is becoming more and more definite and conscious.

We see industry now as a cyclical process. It begins with the determination of what has to be made or done, the necessary qualities of the goods or services in relation to their use; what in war we have to think of as general staff requirements, in peace become community requirements. Goods and services have to be scientifically assessed in regard to the function they have to fulfil. Functional specification—for example, the top speed, ceiling, miles per gallon of a plane—is taking the place of specification by tradition or description. Once we know what is needed we can set about finding out how far those needs can be satisfied; here scientific research comes in. It is at the same time the channel through which new knowledge of materials and methods passes into industry, and that through which demands for yet more knowledge pass back to the universities and scientific institutions.

But research is not isolated in modern industry; it is intimately connected with development and design. It is relatively easy to design and make something that will fulfil the function—there are usually many ways of doing this—but the real art of modern manufacture consists in so designing the product that it fits simultaneously with the requirements of the users and the processes of the factory. Scientific production methods are as important as scientific invention. These methods are not merely technical. It is becoming increasingly realised, through the example of the Soviet Union, that the original concept of the factory as a place where goods are made is a very one-sided one. Goods are made in factories, but people work and live there for a third of their lives, and the production method has not only to be economic but adapted to the capacities and interests of the workers; and this must be done

not only *for* the workers but also *by* the workers, as was first recognised in this country by the setting up of production committees.

Scientific methods have much assisted the development of rational production methods: rigid standardisation of parts and materials and statistical quantity control have led to enormous economies and simplifications. Only in one aspect have they given rise to greater demands: there can be no economy in thought. Higher standards than ever before are required of the technicians and designers.

The integration of science in industry does not end with the manufacture of the product: it needs to be followed into its field of use; it requires servicing; it requires operational research to find out how far it is fulfilling its function or even how far its function is really a necessary one.

It would, however, be perfectly possible to have a set of ideally scientific productive units and yet have an economy which was anything but satisfactory. Integration between productive units is as important as proper organisation of each unit itself. The outer integration can be as scientific as the inner. Close relations between producers and users, and between producers serving common users or drawing materials from a common producer, can be organised and have been organised during the war. But all this cuts violently across the whole tradition and practice of capitalist production. Under capitalism the only way in which such co-operation is envisaged is in vertical or horizontal trusts and cartels in which the interests of the ultimate consumer are rigidly subordinated to the profit motive.

The complexities of modern production processes make it less and less possible even for the most intelligent of consumers to know whether what he is buying is good or whether he is paying a fair price for it. His only evidence for the first is the advertisement, and the money spent on advertising is itself a conclusive proof that he cannot be getting his money's worth. As long as the effective criterion for consumption goods is the willingness of the public to buy, functionally satisfactory and cheap goods are in fact driven off the market by goods readily saleable well above their cost price. This distorts the whole framework of industry; in particular it leads to an unhealthy emphasis on consumption rather than production industries,

starving the latter of capital at the expense of the former—a process which is largely responsible for the dangerous state of our present industrial structure. Even when the profit motive is absent, as in the case of the co-operatives, the prevailing pattern of choosing consumption goods for show rather than for use still persists. Here the state, like the municipalities in the Middle Ages, must come in to protect the consumer and establish good quality and fair price.

The possibility of the scientific revolution in British industry in the immediate post-war years depends mainly on political and economic factors. The legacies from the past in the form of backwardness and distrust of science will have to be swept away and the more modern tendencies to restrictive monopoly broken, before the stage can be set for the transformation. But the present prospects for the world make this a perfectly possible as well as a necessary condition. We are entering an era which will put demands on productive capacity absolutely greater than any which have existed before and relatively greater to our means than they have been since the first days of the industrial revolution. Not only is there the damage in Europe to repair, but this has to be done, in the first stages, without the resources of European industry. While this may be a short-term task, behind it lie the far greater and persistent demands of the hitherto backward parts of the world in Asia, Africa and South America. Here the war has already definitely marked a transition from agricultural communities producing food for subsistence and, to a lesser degree, economic raw materials for export, towards modern industrial communities capable of trading with the older countries on an equal basis. To effect this change, they need not only imports of machinery but imports of technical skill and scientific knowledge. Thus the opportunity and the demand for rapid transformation exist together and the forces that are trying to hold back progress will be fighting a losing battle.

Nevertheless the part that Britain will play in this reconstruction of the world will depend on how realistically we face the needs of the situation and are determined in dealing with the obstructive forces. The test will be whether Britain can produce goods and services whose quality and price can compare on the open market with those of other industrial countries. It is already generally recognised that this cannot be

done without a very considerable refitting of industry in the form of capital goods—new and more efficient machinery and plant. What is not so clearly realised is that both the equipping and the running of the new industries will require the services of a much larger number of skilled technicians and scientists than we can find in the country today or are likely to train unless we make radical changes in our educational system and the organisation of scientific research.

If we cannot greatly increase the number of qualified scientific and technical persons of all grades, from assistants and draughtsmen to directors of research, it is no use expecting any of the benefits that improved methods of production can bring. Already the number of scientific and technical personnel in this country is entirely inadequate to the limited needs of present-day industry. This defect was foreseen many years ago, but became obvious during the war when we were seriously hampered by the shortage of scientific workers; and had to devise emergency methods, such as the bursary system, to select and train them.

The core of the present difficulty is that we are still clinging to a nineteenth-century view of the functions of higher education, namely, the production of a very restricted class of professional men—administrators, doctors, lawyers, etc.—and consequently only give university education to 1½ per cent of our young men and women as against 10 per cent in the U.S.A. and 6 per cent in the Soviet Union. We had, in fact, before the war, the lowest percentage of university-educated people of any country in western Europe. The universities themselves, concerned more with the difficulties of teaching what students they have than with any general care for national welfare, are firmly opposing any substantial increase in students. Nevertheless, if the demand is to be met, new universities will have to be created and many more scientific teachers found. In normal times, where leisurely progress could be expected, this increase would come of itself, as it did in the nineteenth century, from the pressure put by the users—in that case the manufacturers—for suitably trained staff; but we cannot afford to wait for these methods. Unless the government takes the question of the scientific and technical manpower of this country in hand as a matter of national policy, it is idle to hope for a rate of technical change that will close the gap

between ourselves and more advanced countries. What has been done up to now may maintain the present number of students but can hardly increase them. The Universities Grants Committee has, it is true, raised the grants from £2½ millions to £5½ millions per annum. This, however, in effect only raised the total income of the universities from £6½ millions to £9½ millions, which will only just make up for the increased cost of living, and this sum has to suffice for all teaching needs of which the scientific and technical amount to only one-third.

Scientific research itself is also carried on in this country on a dangerously small scale. All responsible bodies who have investigated the question—the British Association, the Association of Scientific Workers, even the Federation of British Industries—agree on this point. While it is difficult to be precise, it is probable that we spend one-tenth of one per cent of our national income, or some £8 millions a year, on industrial and fundamental research in this country. We could spend many times this amount profitably; but, on account of practical limitations due to lack of trained manpower, a figure such as that given by the Association of Scientific Workers, of a threefold increase—that is, £24 millions—seems a reasonable target for the immediate future.[1]

Expenditure of money on research is no guarantee of success, but not spending it is a certain guarantee of failure: modern science simply cannot be done on the cheap. To get the best results from science in industry requires more than the work of a few brilliant men or even the work of a few first-class research institutions. It requires coherent planning of the whole field of industrial effort. Under our present economic system only state action can provide such co-ordination between the needs of different industries and of the ultimate consumer. Actually, we have for many years now implicitly considered industrial scientific research as a national concern, in the first place by the setting up of the Department of Scientific and Industrial Research, and, more recently, by the proposal to exempt research expenditure of firms from income tax. This is, of course, an indirect subsidy; and it is one that should carry with it, in the interests of the public, a guarantee that the research carried out is as much for public as for private benefit.

[1] In 1947 it was about £40 millions. (See note, page 220.)

It is admittedly difficult to find a means by which the state can carry out its function of protecting the public without positive interference in the productive activities of industry. At present, state-financed research in industry is largely concerned with standardisation and the study of technical failures. It is not concerned with research tending to the development of new methods, and this is precisely the research that is most needed. It may be that the establishment in government laboratories of specifications of standards of performance of machinery and products over the whole range of industry will be sufficient stimulus to private concerns to produce goods up to these standards. The stimulus would be reinforced by the increasing degree to which national and local government purchases influence industry. It is also essential that the costs of production should be kept down and that the efficient firms should no longer take shelter behind the inefficient ones. The government, as purchaser and guardian of public interests, must have means of knowing what the real costs are and of criticising prices, not only if the profit margin is too high, but even more because of the use of inefficient or antiquated processes.

To carry out these functions implies a great increase in the range of government-organised science. It also implies a much greater degree of co-ordination. The only way of achieving this, particularly in view of the shortage of scientific manpower, is by creating some kind of general staff for government science. Already we have, under the Lord President of the Council, what is in effect a Ministry of Science, and this organisation is capable of development to meet the new needs if it can enlist the services of the independent scientists of the country as effectively as they were enlisted for the war. Much was learned in scientific organisation through the experience of the war, particularly the importance of the strategy of scientific research, that is, of the distribution of limited scientific manpower to where it was most needed and of using it in a co-ordinated way. We need this lesson most of all at the present moment where there is a serious danger that, control over employment being relaxed, national priorities will disappear. Firms will bid against each other and against the government for scientific workers and research will tend to drift off to directions where the easiest money can be obtained, into such

relatively unimportant industries as, for instance, radio and cosmetics.

It is not going to be easy to get an adequate scale of organised scientific effort in Britain. Apart from general apathy and stupidity, it is effectively opposed by monopoly interests who naturally prefer to keep in their own hands such research as they think worth doing. Besides the external opposition, there is, as in the analogous case of medicine though to a lesser degree, opposition from inside the scientific world itself. The Victorian tradition of "pure science" dies hard. Now this was a very good tradition in its time when it was essential that science should not sell itself body and soul to the vigorous but greedy and short-sighted capitalist of the mid-nineteenth century. The situation today is quite different; science is as little able as industry to function on an individualist basis. It is equally important that the discovery of new truth should not be bureaucratically ordered. But this does not represent an insoluble contradiction. It is perfectly possible, as has been shown for many years in the Soviet Union, and in Britain and the United States during the war, for scientists themselves to organise so as to be able to carry out general directives while actually assisting groups and individuals to develop their ideas freely to an extent that they were never able to do in the pinched days before the war.

As long as the organisation is under the direction of scientists, an adequate allowance for the pursuit of fundamental research will be made. This must be done for two reasons: the first is that it is only on the boundaries of knowledge, and particularly at the meeting of theory with experiment and observation, that important new advances will be made. The second is that it is only in fundamental science that the principles common to all applications can be found. The younger generation of scientists, already a large majority in numbers, if not as yet in fame, fully realise these considerations and they are, particularly through the Association of Scientific Workers, pressing vigorously for a planned science which combines the idea of national service with real scope for scientific effort. It is, however, time to realise that this struggle is not one for scientists alone. The future of Britain as an industrial nation, and with that the future of the tradition and culture which she represents, depends on whether we can, before it is too late, use our

talents and organising capacity to compensate for the damage that has been done by years of stupidity and neglect.

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RESEARCH IN WAR AND PEACE

Science and War

THIS war has been from the start a scientific war and it has been growing more scientific as it goes along. It is the first war in which the applications of science appear without disguise. Complicated apparatus, which would never be seen outside a laboratory in peacetime, is now in use every day at the front, on land, at sea and in the air. Thousands of trained scientific workers are working with such apparatus under field conditions. But it is not only in this visible way, as in Radar or signals, that science comes into the war. Every weapon and every vehicle, every ship and plane, have needed for many parts of their design the application of scientific principles and, in most cases, the carrying out of scientific research. The change, even since the war started, has been enormous. Traditional designs, based on years of experience and which seemed perfectly satisfactory for static conditions of warfare, are gradually being replaced by special and new weapons designed to meet the new circumstances imposed on us by the varied natures of the battle fronts or the new devices of the enemy. Explosives and guns have not only been produced in astronomical quantities but also have been improved in quality largely through the application of scientific research, the greater part of which was only started after the outbreak of war. We have found out, for example, more about how explosives work in the four years of this war than was known in the whole of past history.

Operational Research

Even this use of science is not the whole story. An entirely new branch of scientific work was born in this war—that of

operational research. At first it was considered sufficient to hand out to the services weapons and new devices that were correctly designed and had passed the standard tests. But very soon complaints began to come back that the devices, particularly new and complicated ones, would not work. Consequently, scientific workers who had had a hand in making the new devices were sent out into the field to see what was wrong. Sometimes they put it right there and then; more often they found that they and the designers had not known enough of the conditions under which the apparatus was to be used and that it needed alteration to make it fit the hard conditions of practice. But it was not as simple as it seems to know whether the devices were working properly. The first success or failure in a new radio device or new weapon may make a decisive impression on the user, who will bless or damn it accordingly. The scientific worker knows from bitter experience what a large part chance plays in these matters. He has learned that a long series of observations and of proper statistical analysis of them is needed before the verdict of success or failure can be fairly given. So it was necessary for the scientific worker to keep on the job and maintain a permanent check on performance. This led naturally to a third stage—the statistical study of the military operations themselves. For example, we read in the papers of the bombing of such and such a target in which so many acres are completely destroyed and it is estimated that production at such and such works is down by fifty per cent. That is not a guess. It is an estimate carried out in a very precise and statistical way based on comparison between photographs of German towns and factories that we have bombed, and those of our own bombed factories where we have full knowledge of what damage was done. As a result, bombing offensives can not only be assessed accurately but scientifically planned. With operational research, warfare itself and not only the weapons of war is becoming scientific.

Mobilisation of Science

All this expansion of research activities has meant a mobilisation of science such as we have never known before. A register of scientific and technical personnel was set up just before the war. It is estimated that there were in Britain about 160,000

scientific and technical workers. Of these, the great majority were needed at their original work in industry; a number of others, chiefly the younger men, went directly into the services to operate scientific apparatus. A few had to remain to carry on the vital tasks of training: for now nearly the whole of our university and technical schools are in effect training establishments for special duties in the services. The remainder took on war research in industry or government departments. The normal research departments of the services have all grown to many times their peacetime strength and new establishments are continually being founded. Nevertheless the number of scientific workers available for war research never meets the demand. We should never have managed if we had not been able to speed up and organise scientific work so that it yields far more results in a far shorter time than was considered possible in peacetime. For the first time in history we have got organised science working under high pressure for a definite need. This will probably mean as much to the progress of science in the long run as science has meant to the progress of the war. Thousands of scientists have experienced for the first time how it is possible to work together without loss of freedom or initiative and with a sense of being of important use to their country.

What is Research?

It is from the pattern of what is being done in wartime that we are beginning to see all that scientific research can do: what part it has to play in production, in consumption and in the organisation of our society. The scientific worker has two ways in which he can be useful; first through his special knowledge of science—those parts of experience that have already been analysed by the scientific workers of the past; and, secondly and no less important, by his experience of the way to study things in general whether in his own or other fields. Put in another way, the scientific worker is a repository of scientific facts—if he does not know them, he will know where to look them up or whom to ask; and he is also trained in scientific method, that is, he knows how to set about finding the right questions, getting the answers to them, and knowing how far the answers he gets are worth believing or acting upon.

Scientific research is simply a name for this process. It need not be done by scientific workers and, indeed, a great deal of the best practical research has not been done by scientific workers; but the scientific worker has the advantage of his experience in treating problems objectively: that is, being concerned only in finding the answer and not being made responsible for what that answer is. He also has the advantage of certain techniques which he has learned for measuring things and for checking the results of measurements by a statistical method. Neither of these is of any use in practical war research unless it is combined with the more human qualities of common sense and a judgement of what is important. This is perhaps the chief difference between science in war and what it was in peace; because there are always more problems than can be tackled and many of them are extremely interesting and difficult, and thus scientifically rewarding, but most do not lead quickly enough to the answer of important questions and thus cannot be afforded in time of war.

Science at Work

The real job is finding the right problems—compared with that solving them is easy. Now sometimes problems hit you, more often you have to look for them. The first kind of problem arises when anything goes wrong—the gun jams, the bomb fails to go off, the signal cannot be heard. These problems have the advantage of being definite. It may take some time to find out what is wrong, it may have to be traced back to the factory or even to the design-board, but once the source of the trouble is found, it is not hard to put it right—"trouble-shooting" is a recognised term for this. Very often, however, just putting things right is not what is most needed. In looking into a defect it is often wise not to keep one's eyes too closely glued to the point because it may so happen that the particular weapon is not so much defective as unsuited to its job, and it may even happen that the job is not worth doing. The larger problems are the kind that need to be hunted for. They are at the start more vague and general. It is not: what is wrong with this gadget? but: how can we find something that will do the work of this gadget and be more reliable, simpler and cheaper? or perhaps: how can we find a way of working that

does not need this gadget at all? Some time after the war it will be possible to describe in how many cases the finding of unsuspected problems has been the clue to the greatest success. We are apt to be impressed by the spectacular and the complicated: the particular secret weapon or the giant plane; whereas in the actual course of the war it was the new ways of doing things that turned out to be the most important. The submarine, for example, was beaten, not so much by any particular weapon used against it, as by a study of the actual experience of dealing with submarines in different ways, and with the rational combination of these ways in the tactics of submarine warfare. Where the conditions seemed to call for a particular weapon, the required performance dictated the design.

Finding Problems

In problems which have to be looked for, the form is usually defined in this way: there is a requirement for a weapon of such and such range, accuracy, destructive power, against a specified target. Now it may be possible to prescribe the design from such performance specifications, but usually this means trying a number of different devices to see which one best fits the bill. Here is where another aspect of scientific technique comes in. Science originally separated itself off from common practice, at the end of the Middle Ages, when it adopted experiment—which means doing things on a small scale. A great deal of experiment is just model work. Now once the laws of scale of models are well understood, it is possible to run through a number of alternatives on a model scale in a few weeks which would take years and enormous expense on the full scale. For example, the charges used for blowing up the dams in Germany were first of all tried out with a few ounces of explosives, and the answer scaled up was not far wrong. The results of model-testing—or often of the calculations that can take their place if the subject is well understood—need then to be developed as protoytpes which are subjected to full-scale test, but if the work has been carefully done, they rarely fail or need more than minor modification. As a result it has been possible to step up the interval between the first idea and full-scale production by a degree considered impossible in peacetime.

Tactics and Strategy of Science

All this research and development is, under war conditions, linked together; the organisation is not perfect but it is an enormous advance on anything that existed in this country before. The research is carried out, not by individuals in isolation, but by teams of experimenters who very often follow the thing right through into practical use. It is not, of course, sufficient to make successful improvements here and there; in fact it may actually be harmful. A successful strategy of scientific research is as necessary as successful tactics. That strategy has to lay down what at any given time are the most important problems that seem likely to be solved with the forces available and how to distribute those forces so that the work on any problem gets the degree of support which it needs for the general scheme. At one time it may be night-fighters: at another time anti-submarine work, or the effecting of landings. The big problems, properly studied, give rise to hundreds of small ones each of which must be tackled by the appropriate people. The net result is one big organisation of war scientific research and development which runs through the whole of the services and supply ministries, linking the fighting man at the front with the worker in the factory, bringing together the needs of battle and the possibilities of production. Because in war secrecy is a most powerful weapon, the work that this organisation is doing must remain unpublished and largely unrecognised. But it is no secret that we have built up in this country, and largely during this war, an organisation and a way of organising which, if properly used, can be at least as effective for human welfare afterwards as it is for destruction now.

Research in Peace and War

The differences between war and peace are not only the differences between violence and friendliness. In the past they have been just as much the difference between a society with a purpose and one with hundreds of purposes. In war there is one overriding problem: to defeat the enemy; and that purpose is the touchstone for all activity of all the people in the country; weapons, supply, production, food and health

are all different aspects of the war effort. Every particular action in them must be judged, by and large, as to whether that helps the war effort or not. That is why it has been possible to effect this new organisation of scientific work; but the problems of peace, though less terrible, are not going to be less serious than those of war. People will still need to be fed and housed and have work to do that seems worth doing, and all of this involves scientific problems not very different in kind from those that the war scientific workers are tackling today.

Biological and Social Ends

In scientific language our aim is to provide the best biological and social environment for all mankind. By biological environment we mean such food, shelter and working conditions as allow human bodies from before birth to old age to develop to the full and not to be dwarfed by undernourishment or crippled by disease. By social environment we mean such relations between people as will make them not only feel but know that they are doing their best and getting the best in working together. Science already gives us a pretty accurate picture of biological environment, but finding out what is the best social environment is not a job for science alone. It is something that uses science but really comes out of the actual experience of living and working in a changing society.

Organisation of Science

We would fail to profit from the experience of war if we did not make use of our experience in war science for the better direction and organisation of science in peace. We have already in this country a nucleus of science organised for normal welfare in the Department of Scientific and Industrial Research and in the Medical and Industrial Research Councils. The universities with their research laboratories not only provide the training for the scientific workers but carry out the greater part of the basic research on which all particular development must depend. But their work requires to be multiplied manyfold. In the years after the war we have in this country to face the fact that our material resources cannot be compared in quantity with the vaster resources now being brought into

action in the rest of the world. What war experience has shown is that material resources, though necessary, are a poor index of production. It is not what you have but how you use it that is of critical importance. If we can use the resources embodied in the intelligence and goodwill of human beings we can so multiply the effect of material resources that they become the decisive factor.

What Research can Bring

Research can contribute and contribute quickly to every section of people's work and living conditions. In industry, in agriculture, in medicine, in social affairs and in education, we can at the same time speed up the processes of change and see that the new knowledge obtained is more fully and beneficially used. This has in recent months, and largely owing to the efforts of war research, been recognised by influential bodies and individuals. Scientific research was fully debated in the House of Lords on 15th and 20th July 1943 and a manifesto of much increased industrial research has been issued by the Federation of British Industries in its official capacity. The Parliamentary and Scientific Committee, which has the support of all the leading scientific institutions in this country, is putting forward a series of definite proposals for improving our research facilities in such fields as coal and agriculture.

A motion tabled by the Parliamentary and Scientific Committee, 17th November 1943, reads:

> That this House, recognising that if the United Kingdom is to maintain its position in the post-war world and carry out effective plans for physical reconstruction and social betterment, research and the application of scientific knowledge in all fields must be promoted on a far bolder scale than in the period 1919–1939.
>
> It urges H.M. Government forthwith—
>
> 1. to assure the universities that in planning future development for research, teaching and higher learning as a whole, they will receive support from the state on a much larger scale than hitherto;
> 2. to arrange that education and training in schools, technical colleges and universities shall be directed at the earliest date towards providing a far greater number of persons highly trained in science and technology;
> 3. to set in motion schemes to ensure a substantial and co-ordinated expansion of research activity by private firms, co-operative industrial research associations and state and

other research establishments, and to this end to provide assistance by adjustment of taxation on more general financial grounds and by adequate priority in both demobilisation and by material required for building and equipment.

The Association of Scientific Workers, representing the bulk of those whose livelihood is concerned with science, and who have been pressing for years for full utilisation of science, will do their best to see that any expansion of scientific research is used for human welfare and is not frustrated and diverted to bad uses as it has been in the past.

If this recognition on the part of specialised bodies receives popular support and understanding, it means that we may look forward to a period in which the scientific resources of the country will begin to be used for the first time on a really adequate scale.

Research in Industry

Industry is the basic occupation of our country, and it is upon industrial research that we will come to depend to maintain our general standard of living in a post-war world where many of the peculiar advantages held when Britain was a pioneer of industry have been evened out by the spread of industry throughout the whole world.[1]

[1] Extract from Sir Harold Hartley, F.R.S., *Industrial Research—What it Means to British Industry* (1943):

The prosperity of Britain after the war will depend more than ever before upon the efficiency and progressiveness of our industries. The loss of our foreign investments and the possible diminution of the payments to us from abroad for services rendered will necessitate a considerable expansion in the value of our exports if we are to increase or even maintain our standards of living. Furthermore, this increase in exports will have to be brought about despite the industrialisation of other countries which before the war were mainly producers of raw materials. Success can only be won if our products are better, more attractive or cheaper than those made by our competitors or in our customers' own country.

Similarly, in the home market, our own products must hold their own, and we must make the most of the limited range of our native raw materials. This formidable task can only be achieved by using to the full our inventiveness and technical skill, both to increase the efficiency of our older industries and to develop new commodities which will hold their own in the markets of the world. In the nineteenth century our natural genius and craftsmanship gave us industrial supremacy, but we were then cultivating a virgin field and, until the close of the century, we had few competitors. Now the position is very different, not only because of the growth of industry abroad but because the easy inventions and obvious developments have already been made. Nature now only yields her further secrets as a result of much more prolonged and careful searching. Haphazard enquiry must be replaced by organised and systematic study.

Nevertheless, despite some outstanding exceptions, in this country there has not been a general appreciation of the value of science in industry.

Industrial research can offer us both new materials and new processes. Until recently we have depended very largely on matérials either given to us by nature, such as wood and stone, or produced from natural materials by crude processes as in the making of metals or paper. In the last few years, however, we have begun to learn how to make really new materials to order such as in rayon or plastics. This process is bound to accelerate. There will grow up a keen and useful competition between the natural and artificial products, both being used by research as required to produce the most desirable results. The textile industries need not be ruined or even seriously disturbed if they keep their research up to date and modify their methods and processes to deal with new fibres. The building industry can use plastics and glass along prefabricated lines to the greater benefit of the people who will want new and better houses.

It is in the way of making things as much as what is made that scientific research is likely to make the greatest changes. Take coal, for instance: we get our coal in the most toilsome form of human labour underground; we use it for the most part in the most wasteful way in fires and furnaces. All this can be changed. Open-cut mechanical mining replacing pit methods for surface seams, and underground gasification as practised in Russia for the deeper seams, may in the end abolish mining as we know it. In the meanwhile much can be done to improve both the efficiency and health and comfort of the miner. Coal utilisation is now being taken up in a big way. It is proposed to spend some five million pounds on research alone. A trifling change in our fireplaces may almost double their efficiency for heating rooms, and with the grading and scientific treating of coal industrially we may be able to extract and not to waste the greater proportion of the complex substances which it contains.

Research in Agriculture

The war has shown what can be done if we are put to it, in

It is impossible to avoid the conclusion that if this country is to maintain its position in the world markets, our industries must greatly increase their attention to research as soon as the progress of the war makes it possible. There is danger in delay: markets once lost are not easily regained; and industrialists must be taking active steps now to organise this aspect of their post-war activities.

getting real value from our own land. In a bare two years we have practically doubled the produce of British agriculture and that with far smaller labour resources. For the first time agricultural processes are being rationally planned, and the results of agricultural research, for which this country has always been famous abroad, are being used at home.[1] We will want to conserve and increase in peace the advantages we have gained in war. We may not want to grow the same things as in wartime but no one wants to go back to the depressed and inefficient state of pre-war British agriculture. And research has many more things to offer in agriculture in the form of better utilisation of the land for crops, through plant-breeding and manure, for the vast improvement of stock-breeding, for artificial insemination as first practised in the Soviet Union, and through more rational methods of food growing and processing which can be developed on the basis of war work. Food and agriculture were linked together in the war; by keeping them together and seeing that progressively better standards of the right kind of food are available to everybody, the general health of the public, and particularly the health of the growing child, will continue to improve at a still more rapid rate.

Research in Medicine

Research in medicine has its own contribution to make. We are just passing through one of the most remarkable revolutions in the history of medicine: the beginning of an age of chemotherapy dreamt of by doctors for many thousands of years, where the medicine really cures the disease and does not merely relieve symptoms. Sulpha drugs and penicillin are probably only the first heralds of a series of drugs with which we may reasonably hope to be able to deal promptly and completely with every disease caused by foreign germs or parasites, and to minimise the after-effects of wounds and burns. For the other diseases of degeneration or faulty growth like cancer the way is not yet clear, but we know enough to realise that we shall never cope with them without putting a much larger effort into research in this field than we have done up to date. And it is important to remember that we cannot

[1] See speech by Viscount Bledisloe in the House of Lords Debate on Scientific Research, 10th July 1943.

just do research on the problem itself. It is not by studying cancer alone that it can be cured but by developing a many-sided study of chemistry and biology; in other words, great discoveries can only come out of a foundation of fully cultivated basic and applied science.

Research in Social Science

Before the war many people felt grave doubts about the value of all this scientific research when they saw how it was being used so largely for the preparation of mass misery and slaughter. Now we have had the misery and slaughter and we hope we are near the end of it, and everyone in the United Nations feels that when it is all over science must not be used for such purposes again, but no amount of improvement in industry, agriculture and medicine alone is going to ensure that. We have to extend the field of science a good deal wider and study fearlessly the structure of our own society and its effects on the individuals who are part of it. The social sciences —economics, history, education, psychology—are in need of far more research than they have ever had in the past. It is not often realised that a very small proportion of the money spent on research went to those sciences. That has to be remedied. We shall never know how to deal with our social problems unless we first understand the structure of society.

The natural sciences have come to be what they are because all the time practice has run along with theory, providing an incentive and at the same time imposing a test of reality on everything the theoretical scientist thought. One reason why the social sciences were so neglected was because they did not have this opportunity for practising what they preached. In the world after the war we have got to see that we not only know more about our society but are able to act on our knowledge. The making of the best social environment is not something which can just be prescribed like a biological environment; it is more free in the sense that it is actually being built by the whole of the people living in that society. It is only in so far as they are conscious of the working of society that they can build a better one, but it is also in the process of building that better society that they discover more and more of its structure.

Preserving the Organisations of War Science

The needs we have for science after the war will require a great expansion of scientific activity. We have got to put Churchill's slogan, "Food, work and homes," as a peace aim to take the place of the war aims once the war is won. A common aim also means that we must preserve what we have learned in the war about using science positively to get sound and quick results. We cannot afford to go back to the period when it took anything from fifty to two hundred years to get a new scientific idea across in practice. The war has taught us that we can succeed if we use science to find out what we really want and not only to get what we think we want. This means keeping the machinery, even more, the spirit, of scientific team-work and organisation going in peace. The scientific workers themselves who have had the experience of war science will want to work this way.

Science and the People

One of the most important effects that the war has had on the scientific worker is bringing them into contact with other people who are working with and applying the results of their researches. This is something that we want to maintain into the peace. It is no use having millions of pounds spent on science or training thousands of research workers if these form a caste apart and the result of their work is just consumed and not understood. Science is not a gift for the few, it is the common property of all; but it is a property not to be had without the effort of taking possession of it. In the world after the war we shall need two things: first, to provide a far more widespread education in science so that every new citizen comes out of school with a general knowledge of what science can do and some particular experience of his own, whether it is bird-watching or chemical experiments, which convinces him of its general value; and, second, to ensure that the work of the scientific workers is understood and shared by the people at large. Science is itself a fascinating and exciting occupation: it is as thrilling as any good detective story, but it does not want to be privately enjoyed, it has to be shared in by all to get its full value. In war research many of

the ideas and a great deal of the actual observations have come from or been carried out by people without scientific training. Every type of research—industrial, agricultural, medical and social—can and should involve the co-operation of the factory or field workers, of the patient and the parent and the citizen. Science is after all only a way of finding out how to get what we want. If all of us, scientific and non-scientific workers alike, get together on this job in an orderly way and avoid the distractions of prejudice and interest, we will all the sooner find our way and get our desire.

1944 (Commissioned for but not accepted by the Army Bulletin of Current Affairs)

LESSONS OF THE WAR FOR SCIENCE

WE have heard much in the last few months of the contributions of science to the war. More than in any previous conflict scientific devices and scientific method have been employed with success, and, in the end, with decisive success. The gift has not been one-sided; particularly in the democratic countries, the total and voluntary mobilisation of science, for a purpose which scientists recognised as a valid one, may be found in the long run to have enriched the content and method of science quite as much as it contributed to the defeat of forces which would have made science for ever impossible.

There is a very cogent reason why the advancement of science should tend to be associated with the prosecution of war. In human history up to now it is only in war that the whole energy of a country is turned to one definite end—the defeating of the enemy; and it is particularly in war that this end can be achieved most effectively by the analysis of new situations and the introduction of new methods, operations which call for the techniques and equipment of science. Accordingly, in war, the economic check which limits the expenditure of effort, discovery and achievement is lifted and the potentialities of human intelligence can express themselves without the usual traditional obstacles. All these things are bound to have a stimulating effect on the body of science itself.

If it were not for this, it might well be that the interruption

of the ordinary studies of peacetime science, the removal of research workers from their customary laboratories and the cessation of normal international exchanges would have interrupted the continuity of scientific research to a possibly irreparable extent. Far from this happening, scientific effort flourished and scientists were fully employed, if not in their usual branch of science, in most cases on some other branch which provided them with experience, both outside and in science, which they would never have obtained otherwise.

The contributions of war to science were both direct and indirect. Many of the researches carried out with an ultimate military purpose necessarily involved intense fundamental research, leading to results which are of the same validity as those which might have been carried out more slowly or, perhaps, not at all in peacetime. The most obvious examples are, of course, the contributions made to nuclear physics by the work for the atomic bomb, the contribution to electronics and the development of Radar, the much greater knowledge of disease and epidemic control through the use of penicillin and D.D.T., and innumerable advances in the fields of synthetic chemistry, notably in the production of synthetic rubber and plastics. It is to be hoped that these scientific results of war research, carried out both in Allied and Axis countries, will be fully collated and published without delay: but, even without that, the experience gained by the people who took part in them is bound to have a fructifying effect on the progress of science.

As an example in my own experience, I can cite the value to science of the work carried out in this country, in France and in the United States on research into ordinary explosives and their effects. The study of shock and blast waves which was undertaken in order to understand explosive mechanisms involved much real fundamental mathematical and physical research. The shock wave, with its intense localised pressure, is a disturbance transmitted in a way which transcends the ordinary assumptions involved in the small-amplitude waves of sound. Temperature and pressure effects of explosive shock waves go beyond the ranges ordinarily studied in the laboratory and, in certain cases, approach the conditions of stellar atmospheres. The study of the reactions that occur in explosives led, for example, to the formulation of a quantum mechanical

theory in which all the properties of the explosive could be deduced from a knowledge of the quantum levels and pressure properties of a number of simple gases. At least equally important was the entirely new knowledge of the transmission of plastic waves in solid media and of hydrodynamic disturbances in liquids, both of which are likely to be of the greatest use to basic engineering theory. In the process of studying its effects experimentally, a number of new instruments have been developed which will be of the greatest value in the analysis of all high-speed phenomena. From this example the wide range of experimental and theoretical information derived from the study of a single practical topic can be seen. Such examples could be multiplied in nearly every scientific field. When we remember also that all these researches were carried out under the guidance of the most expert theoretical and experimental physicists in their field, with resources such as none of them had ever possessed before, it will be seen that the net contribution of the war to the actual content of science has not been negligible.

If this were all, however, it might still be argued that more could have been achieved by the same people if they had been allowed to continue their peacetime researches in the ordinary way. Less details might have been found out about things that were already known in principle, but there would always have been the chance of entirely new discoveries which, in the concentration of war, either would not be made or could not be followed up. This argument would be very difficult to sustain if we consider also the greater experimental facilities available and the stirring up of the minds even of senior scientists by contact with unusual problems. But the direct contribution of war science to peace science is only a very small part, in any case, of the valuable lessons of the war. Much more important is the new attitude towards science that was engendered in the war and the new integration that grew up between science and practical human activity. The war taught scientists not only to work but to think in a new way that can be summed up in the two words "infiltration" and "integration." As the war proceeded the scientific workers found themselves less and less isolated and more and more part of a general directed effort. By coming closer to actual experience, they learned the existence of problems at first hand,

and also the limitations which are inevitably imposed on types of solutions that can be used in real circumstances by actual people. By ranging all the way from the front-line soldier, sailor or airman to the High Command, or from the worker at the bench to the board of directors, they appreciated as they never had before the relative functions of analysis and discovery and those of command and execution. At the same time that this process of infiltration was going on, the work of science was being integrated into an increasingly ordered effort to achieve definable ends and scientists themselves learned the virtues and the difficulties of effecting this organisation. In all, the war was an educative period for scientists that few who took part in it will come to regret, even from the point of view of the degree of their contribution to their own particular peacetime scientific subjects.

It is interesting to note that the scientists in the Axis countries did not enjoy these advantages; for all the lavish assistance given to the scientific development of new weapons, the scientists were not trusted with the development and utilisation of their own ideas. There was no real infiltration of the military machine and little integration of scientific effort itself. All we are now finding out about science in Germany and Japan shows the waste of the capacities of scientists which is inherent in the essentially reactionary character of the Nazis and Japanese militarists, who both failed to understand and mistrusted their scientists.

The full integration of science into the war effort took place somewhat slowly and haltingly in this country. This was to a certain degree inevitable; the mutual education of scientists and soldiers could not take place all at once. But towards the end of the war, both in Britain and America, conditions had so improved that it is possible to see in them some approximation to a new and fruitful relation between scientific effort and the productive and operative forces of a modern state that goes far beyond the requirements and possibilities of war itself. The drive that led to this position was, of course, the direct polarisation of all effort to winning the war, and the increasingly intelligent understanding that this polarisation implied a full utilisation of resources under a system of well-thought-out priorities.

We had in this country, and to a lesser degree in the United

States, an absolute shortage of trained scientific men at all levels from draughtsmen and laboratory assistants to theoretical research workers. We therefore had to make the fullest and most effective use of those we had, and this led to a tacit acceptance of a principle which we always should have adopted, that of making man rather than money or tools the measure of the effort expended. If anyone could be found with the capacity to analyse, initiate and direct scientific research and development, he was given full scope and money to do so, and, as we know from the achievements of the war, this was the secret of our great successes. It was most astonishing and invigorating to the academic scientist, cramped for years in a small laboratory and perpetually begging from this or that charitable fund for minute grants, to be allowed to spend thousands of pounds where he had previously spent ten pounds, and to engage assistance which effectively enabled him to give his time to the major problems and not to have to worry about gas leaks and typing. This scope resulted only in the rarest instances in extravagance or wasteful spending. The need to get the answers in the shortest possible time imposed an effective economy on expenditure. Planned experiments took the place of the old haphazard trials and demonstrations which had been usually more expensive, and, because they almost invariably altered all the factors at once, provided no reliable answers. The freedom of scope for experimentation and assistance is a lesson which will not be lost on the scientists who experienced it. It will be of particular importance in the next few years when we are bound to suffer for lack of men to carry out the very much increased tasks which will have to be dealt with by science and where it is more than ever important that we should make the fullest use of our few capable workers. The principle first enunciated by Professor Blackett, that allocation of money to science should be made in the measure of what a competent scientist can usefully spend and not according to what he can just manage on, should be the basis for our post-war science.

Almost equally important as a lesson of the war is the value of the greater integration which was achieved in scientific work, partly through a more rational organisation and partly through the function of an effective positive information service. The organisation of science in the war service was naturally of

somewhat gradual growth. Much of the earlier organisation tended to be bureaucratic and time-wasting, but with growing experience there grew up in the service ministries a close but flexible network of committees and panels manned by active scientists and in constant touch with service requirements. As time went on, this network extended between the services and linked up with the scientific war effort of the Dominions and of the United States, but, regrettably, never with that of the Soviet Union. This system provided what had been previously the function of the scientific societies, that is, careful discussion and interchange of scientific opinion, but it had also a much more positive function in laying out lines of attack and in determining priorities. In this way the scientific work itself could be carried out in a multiplicity of actual experimental stations—government, industrial, university—and yet not lose its coherence or general direction. Further, this direction was exercised by scientists themselves, at least in the latter part of the war, and was consequently sufficiently reasonable to be for the most part acceptable to the main body of scientific workers. Out of it emerged general concepts of organisation of science which will be of permanent value.

In the first place the distinction grew up between two kinds of studies of radically different characters—"object" studies and "subject" studies.[1] In "object" studies the ultimate purpose was kept steadily in view, whether it was the defusing of bombs or the prevention of malaria. All the different approaches to the problem were correlated in the light of this object and different sciences were called in to make specific contributions. "Object" committees had necessarily much closer association with the user than had occurred in peacetime, but the user did not dictate the research or even put specific demands for equipment. As the war went on it became more and more possible to express what were known as staff requirements in scientific terms, capable of achievement through research and development.

On the other hand it was often found that a large number of different objectives came to depend in some degree or other on a single field of science. This gave rise to the "subject" committees which ranged all the way from the august Radio Board, which controlled the development of telecommunica-

[1] More recently these have come to be called "convergent" and "divergent" research.

tions and Radar for an enormous number of service users, to the humble "Mud" committee which considered the properties of mud in relation to service needs for civil engineering and transport. "Subject" committees were more homogeneous scientifically than "object" committees, but, correspondingly, had a wider range of users. A simultaneous development of both systems of organisation is immediately applicable to peacetime science. Many of the objections that have been raised to the organisation of science have rested on the fact that a distinction between them has never been clearly made. Many scientists had only learned to think of organisation as organisation with an object, usually an applied object, and were very alarmed lest the concentration on that object should prevent the natural, inherent development of particular scientific disciplines. But the parallel development of "subject" organisation should overcome this difficulty and, indeed, add very much both to the scope of scientific research and the number and novelty of problems presented by providing what has always been a notable gap in scientific organisation—a place where users and research workers can meet on the research workers' ground.

One other bugbear of the opponents of scientific organisation has been the danger of the dragooning of scientists which such organisation would necessarily imply. War experience has on the whole shown that this is not necessary. In fact the most successful scientific efforts of the war were combined with the greatest freedom and scientific initiative on the part of the scientific workers. In one of the most important institutions in this country, there was a regular weekly "soviet" of the research workers, who discussed the objectives as well as the details of the work they were doing. The pronouncements of the various atomic scientists groups in the United States shows to what extend a real democratic spirit was also present there. Where there was over-direction of scientists, it was usually because either the directors in question were not themselves scientists but were civil servants or military men, or because they were scientists of the old school of government science, and in either case it nearly always resulted in slow and ineffective working. In a few cases this became so bad that the system was changed and the immediate beneficial results showed that democratic collaboration is at least as important in wartime as in peacetime science.

Military science has often been objected to because of the secrecy it entails, but, paradoxically enough, this is less apparent in wartime because so many scientists are absorbed in war, and because the need for rapid communication of results makes it imperative for there to be a minimum of secrecy inside war science itself. This, of course, was not always realised: notably in the early years of the war and, very fortunately, all through the war in the Axis countries. By preventing the scientist from acquiring full knowledge both of the applications for which his work was required and of the parallel and contributory work of other scientists, initiative was hampered and even absurd results were obtained. It is often essential for a scientist to know why a question is being asked before he can give a sensible answer to it. The early stages of the development of atomic energy in the United States were seriously hampered by a security system which prevented one group of scientists from knowing what the others were doing. Towards the end of the war, however, these difficulties were overcome and a far more effective system of scientific communication was organised than most scientists had enjoyed before the war. Not only were there very efficient abstracting services and a free circulation of papers, but what was even more important, there was ample opportunity for scientists to go to discussions and to visit each other's laboratories and field stations all over the world. The advantage of air travel for the speeding up of scientific communication is something that scientists will not forget and it is to be hoped that it will be equally available to them in time of peace.

However excellent in detail was the conduct of scientific research in wartime, its value to the actual winning of the war would have been much smaller if there had not been what Sir Henry Tizard has called a "general strategy" behind it. We scientists had much to learn from the traditional modes worked out through centuries of experience in the military field. The keen scientific worker who could attack and solve his problem was invaluable, but he was not necessarily capable, on account of his training, of seeing that the problem he was interested in solving was not the most important problem at that particular time, however technically interesting and absolutely valuable it might be. For that it was necessary to develop the type of scientific staff which, though it was never

formally constituted, existed in close connection with the General Staff, and dealt not only with supply but also with planning. This staff learned the value of establishment of priorities and concentration of effort, and also the even more difficult task of abandoning attempts even when they offered a fair chance of success, because the time for the use of them had passed. The strategy of war science did not exist in a vacuum. If nothing but scientific considerations existed, there would be hundreds of different ways in which attack could be made on the infinite territories of ignorance that surround us. The choice must be determined, by and large, by short- and long-term human requirements. These requirements can easily be seen in wartime as the achievement of victory. In peace, they are less easy to see but are beginning to be recognised as the removal of want and fear.

The need for strategy in the application of science to war was the greater because of the disproportion between the demands of war for science and the supply of scientists. The total scientific effort of the country had to be considerably stepped up in an extremely short time. To a certain extent this was done by the more efficient employment of the scientists we had, which was made possible by the creation and operation of the Central Register. Once this Register came to be administered by scientists, it showed itself to be absolutely essential in the strategy of the scientific war effort in allocating appropriate workers to the different requirements. Naturally, the proportion of the requirements in the different sciences were not the same in war as they had been in peace. In the early stages of the war this led to important groups such as chemists and biologists being somewhat neglected, but later it was found that scientists were very much more interchangeable than their specialised training would have led us to expect, and that, particularly in new branches of scientific war work such as operational research, scientists trained in all subjects could make equally significant contributions. The Central Register provides us with a new and, it is hoped, permanent addition to the armoury of science. By its intelligent use it will be possible to predict sufficiently far in advance the needs in different scientific fields and, in relation to university programmes, to train the appropriate number of scientists. War experience has already taught us the need to keep our scientific

manpower flexible by avoiding over-specialisation and inculcating general scientific method into teaching.

Even, however, when the most careful husbanding and wise distribution of trained scientists was effected, it was clear that we were far short of the scientific manpower requirements.[1] Here again the war has led to an innovation which we must try to preserve in peace. The system of science bursaries made it possible, for the first time in our history, to give to all those who had the ability to profit from a scientific education the opportunity to get one. The conditions, of course, were still not ideal. The demands of the fighting services and war industry naturally and rightly trenched on the supply of potential scientists and consequently the standard for war bursaries was not as high as it might have been. The extension of the system to higher education in general and not only to scientific education would be of enormous value in peace. Before the war, England gave higher education to only 1½ per cent of her citizens and this 1½ per cent was not chosen on the grounds of ability. It is considered that some 8 per cent of the population would in fact be able to profit by university education and it is most important that we should see that they get it, and that the all-too-low standard of teaching should not be wasted by training those who have no better claim to education than the wealth of their parents. Even if this were done, the children of educated parents would have very considerable advantages, as they, in fact, get additional education from a very early stage, which is denied to the children of many manual workers. The same problem has been recognised in the United States where a far higher percentage—10 per cent—receive university education. In the Bush Report it is pointed out that this privilege is practically exclusively determined by parental wealth, and that there is an

[1] The United States had a very similar though more intense experience in mobilising scientific manpower. During the war total national expenditure on research rose from about 350 million dollars, of which only some 70 million dollars was provided by the state, to not less than 800 million dollars exclusive of atomic-energy research expenditure. This vast increase did not, of course, mean that the number of scientists in the country had been doubled; it only meant that they had been able for the first time in history to spend money freely on research. Nevertheless, the situation in America, where the expenditure on research was several times more than anyone imagines can be spent in this country, showed research expenditure there still to be dangerously low. The figure proposed now (1949) is 2000 million dollars. In the now well-known Bush report, the demand for a much larger number of trained scientists is repeatedly made.

enormous waste of ability which the report recommends should be remedied by the promotion of national scholarships on a large scale.

The proper allocation of individual ability to the tasks most suited to it has been much facilitated as a result of the experience of the selection boards which have operated in all the services. For the first time, scientific methods based on appreciation of psychological factors have been used on a really mass scale, and in so doing they have led to a much fuller appreciation of the relatively unknown factors involved. The selection of human beings is, of course, far more than sorting into categories; it involves attitudes formed in family and social associations quite as much as any inherited trends, and it is therefore conditioned by social evaluations of different possible occupations. All these factors will have to be borne in mind in further application of selection methods in peacetime, but the relatively rudimentary vocational guidance which existed before the war will undoubtedly gain enormously from war experience, and is likely to become a permanent feature in the transmission of our culture to future generations.

Another lesson of the war closely allied to this is the experience of training comparatively uneducated personnel in the handling and maintenance of complicated scientific apparatus. The methods developed in training, particularly in the R.A.F., represented an enormous advance in the application of scientific methods to education. It is to be hoped that these lessons will not be lost and will be extended to cover the whole range of peacetime scientific occupations, for it is certain that we shall need not only a much greater supply of university-trained scientists, but that a large proportion of the population will need to have practical mastery of the new appliances which are bound to be increasingly used in industry and in everyday life.

All the contributions of the war already mentioned are in some sense simply extensions of methods or ideas existing before the war. We have had organisation of science; we have had selection and training for many years. The war has, however, introduced what is virtually an entirely new technique in the application of science, operational research. Though having some affinities with certain commercial inquiries such as market research, it arose independently in the war out of immediate ends and developed so rapidly and so effectively

that by the end of the war it was considered a necessary adjunct to every aspect of military affairs. At the beginning of the war new and essentially scientific devices, such as Radar, were being prepared by the research departments of the services. To hand these over directly to service personnel in the field just would not do. Prejudice against new gadgets and unfamiliarity with their handling was combined often enough with practical unsuitability of the apparatus, which had been designed by people of great scientific competence but with little knowledge of the physical and human factors that occurred under service conditions. To remedy this state of affairs, some of the actual scientists who had been concerned with the development were sent out to stations to supervise the use of the new apparatus. What might have been a mere servicing job grew into something much more important. For the first time immediate, personal liaison was effected between the scientist and the soldier, and the mutual education that grew out of it made the acceptance of further developments far easier. But it did more than this. The scientists in the field began to study the practical performance of their devices and this study took on an increasingly quantitative and statistical aspect. From this study they began to deduce what were the real requirements of the devices as distinct from what they had been imagined to be by the military staffs, and this led at once to new directions in development. But the reciprocal process was also at work. Scientists began to see what the operational possibilities which they either knew or could devise were likely to be, and to influence operations in relation to these possibilities. As a very distinguished soldier said at the end of the war, "At the beginning tactics determined weapons; at the end of the war weapons determined tactics."

The first stage of operational research was concerned with physical devices, but once it had started it could not stop there. From the analysis of performance of particular weapons came naturally by extension the analysis of performance of a particular tactic, such as air submarine-chasing or the bombing of targets; all the factors, and not only the instrumental factors, had to be brought in. Such factors involved many human elements: the morale or fatigue of the soldier or airman, their state of training, the reactions of the enemy; in fact very soon there emerged the beginning of military science in the modern

sense, that is, a predominantly quantitative and statistical estimate of the operations of war. It is greatly to the credit of all ranks and branches of the services that this development, which could so easily have been resented as an intrusion, was on the contrary welcomed and encouraged. Before the war was half over operational research was already an accepted branch of operations; new and small to start with, but still taking its place beside the logistical and intelligence branches. It developed an esprit de corps and method of its own and started vigorously recruiting among scientists of all kinds. It was found, for instance, that biologists and social scientists had a flair for operational research equal to if not greater than that of physicists or chemists.

Operational research led not only to greater understanding in detail of the operations of war, but to a much clearer integration of different types of operations. As the war went on, combined operations, whether by land and sea, land and air, or all three together, became the rule rather than the exception, and the bridge between the very diverse approaches of the different services was often effected through operational research. In this way several general principles emerged which have far wider application than merely to military operations. One of the most important was the intelligent use of variation analysis. The urgency of war makes it of cardinal importance that the improvements should be made first where the greatest return is to be expected for the least effort. By a study of a sufficient number of actual cases where there had been a considerable range in variation in all the factors affecting the success of the operation, it was usually possible to select one that seemed the most promising and then by deliberate variation to determine its effective return. At this stage it was often possible to introduce trials and purely physical calculations. These, however, could not be relied on implicitly because they inevitably omitted the operational factor, that is, the unreproducible character of the behaviour of men under the actual circumstances of battle. The neglect of this factor had in fact vitiated many of the earlier efforts at scientific analysis of warfare. What seems physically attainable, what may even be attained in trials, often proves entirely unattainable in battle. If it were not for the operational factor war itself would become an exact science. Indeed it is not difficult

to analyse operations in such a way as to predict victory with certainty. If this could have been proved, then war itself would cease to have any significance, for no one would engage in it on the certainty of being defeated. But, unfortunately, to reach such a result some assumptions as to human characteristics had to be made, such as: "All generals are infinitely intelligent." Operational research, dealing as it did with actual achievement, provided a quantitative corrective to theorising. It also enabled the scientist to appreciate the human qualities of command and performance and the conditions under which it is necessary to make and adhere to decisions where many of the vital factors cannot possibly be determined in time or at all.

Operational research was concerned, in the latter stage of the war, quite as much with the choice of problems to be attacked as in the attack on the problems themselves. It was clear that however operational research groups were increased they would never be able to deal with more than a small fraction of the soluble problems of warfare. Although it would always be necessary, in order to establish the value of the method, to deal with day-to-day problems or those specially brought up from the staff, it was also necessary to have some guiding principles in planning the general use of operational research. The aim was to provide the most effective results in the shortest time. This determined priority of problems on the basis that those which made the product of three roughly assessable factors the greatest should come first. The factors were the military importance of the solution, its tractability by any know scientific methods, and the speed at which practical results might be expected. It would have been easy but wasteful to concentrate on the solution of many small but unimportant problems that could be handled quickly. It would have been equally wasteful to embark on vast schemes for reorganising the whole of warfare on a scientific basis. Further, small improvements were deliberately not looked for. At one stage in the war, no improvement in the performance of any weapon of less than one hundred per cent within a year was worth considering. In peace the conditions of urgency will be less marked, but they will not be absent. All that will happen is that the time-scale can be increased and the standard of desirable improvement lowered.

The knowledge accumulated in operational research and, perhaps even more, the experience of those who took part in it, may prove one of the most valuable contributions of the war to science. For operational research has clearly important applications to the post-war situation; the same methods and, very often, the same men can be—and some of them have been already—used for the solution of peacetime problems, in such fields, for instance, as building and the reconstruction of our export trades. We have found here a necessary link between laboratory science and industry.

One feature of operational research is particularly important in this respect. Operational-research teams, as already mentioned, included social scientists; in the new studies that will be needed as a basis for peacetime policy, even greater attention will have to be paid to the social aspects. For, complicated as are the human problems of war, there is in war an overriding general directive and an institutional discipline which is necessarily lacking in peace, where the extremely diverse and often conflicting desires of large numbers of individuals have to be taken into consideration. Here, the social scientists who have to find out what people want and need, and the physical scientists who hope to find the ways to satisfy those needs, will need to work together in the closest collaboration.

The original implications of operational research are already making themselves felt in peacetime economy. In principle it amounts to the statement that any human activity and any branch of that activity is a legitimate subject for scientific study, and subsequently for modification in the light of that study. Once this is accepted in practice, which implies the provision of research workers to carry out these studies, the way is open to a new level of man's control of his environment, one in which economic and social processes become scientific through and through. This is already happening in productive industry. We are witnessing what is really a new industrial revolution in which statistical and scientific control and rational planning and design are taking the place that prime movers and simple mechanism did in the first industrial revolution. Industrial processes are now seen to represent cycles of performance in which the needs of the consumer determine production and are in turn modified by the results of that production, leading to a progressively greater degree of satisfaction at a steadily dimi-

nishing social cost. The stages of the cycle are also becoming clearer.

We have first of all the study of the needs of the consumer, a study which is becoming more and more scientific. We are now learning to distinguish between expressions of "wants," which indicate the attitude of the consumer in relation to his past experience and his expectations, and "needs," which represent the goods or services which will in fact satisfy them. The determination, successive approximation, of these goods and services is a process in which we have learned much from the war. There, the distinction between staff targets, where the general operational desiderata were stated, and staff requirements, when these were made precise in relation to actual possibilities of design and production, became very clear in the latter part of the war. Staff requirements can only be assessed if technical factors and production possibilities as well as operational needs are kept in view, and imply close integration between the sections responsible for determining requirements and the production sections.

To meet staff targets and staff requirements was the main task of research and development departments. These two aspects had tended before the war to be kept rather separate, and one of the lessons of the war has been to draw them together. Particularly in fields where rapid advances were an urgent necessity, as in Radar or gunnery, it was necessary to expand these sections so that to a certain degree they acted as the major channel between requirements and production. Research and development are, however, essentially different modes of attack on practical problems. Research is concerned with the limitations of possibilities by material and known human factors; development has to take into account such factors as existing production facilities and economic considerations. Into development there enters too the element of design where an apparently arbitrary selection is made between possibilities but in which the specifically human and as yet known scientific factors of skill and art come in to supplement science.

After development comes production. At the beginning of the war there was, particularly in the service departments, far too great separation between these phases of the productive process. It was soon realised that the actual designs submitted

by the development departments, which were often very out of touch with modern productive processes, were most unsuitable for production as given and had to be drastically modified—often seriously to their detriment—before they could actually be made in quantity. This difficulty was later overcome by the introduction of production engineers into development sections and by a much closer relation between the two departments.

Quite apart from their integration with research and development, production methods themselves came to be influenced more and more by scientific considerations. One of the great contributions of the war to industry was the introduction of statistical quality control, and with it the possibility of far better quantitative planning of production processes. In other words, it was recognised that the production process itself could be scientifically studied and scientifically controlled.

The final phase of this productive cycle involving the examination of the performance of the products and the degree to which they satisfy the original requirements has already been discussed as a starting-point of operational research. It merges completely with the first phase of assessment of needs and requires the same survey techniques. In peacetime, once it can be divorced from the elements of commercial competition and so be free from the suspicion of deliberate bias, the subsequent servicing and customer studies will be a most valuable guide to the continuous improvement of production. These phases of the scientific control of the production cycle are clearly interdependent, but more is required than the necessary liaison between people carrying them out. There must be some mechanism such as was provided in the war by the scientific directorates and their advisory committees, and which has begun to appear in peace as "industrial working parties," to determine the major lines of policy and to allocate the scientific effort according to where it is most likely to be useful.

In the development of the atom bomb we have had an example, on the largest scale and the maximum intensity, of scientific enterprise on the new model. There pure scientists, engineers, administrators and soldiers all worked together in a co-ordinated way according to a definite plan, flexible enough to allow for the necessarily unforeseen contingencies of scientific discovery. In some ways this organisation was as important an

invention as the liberation of atomic energy itself. The lesson that it teaches is that it is possible, given a definite end and a social will to achieve it, to attack any problem and to reach practical success in a small fraction of the time in which it might have been reached by the uncoordinated methods that ruled before the war. It shows that the actual speed of advance is limited by the amount of scientific and technical man-power together with their accompanying material resources that are put on the job. Only when this exceeds a certain value is progress likely to be held down to the limits fixed by the obstinate and unalterable properties of material systems or the almost equally obstinate difficulty in the solution of intractable intellectual problems.

The choice whether to push matters to these limits is a social choice: it depends on an overall assessment of what tasks the community most needs carrying out, but this in turn, within limits, is a scientifically determinate question. Choices in the general direction of the scientific war effort had, indeed, constantly to be made during the war. In the early phases they were frankly arbitrary choices by eminent politicians, guided more or less by self-chosen or official advisers; towards the end a more scientific organisation tended at least to modify this arbitrariness. But certain arbitrariness must and will remain; there often comes a point when it has to be recognised that we lack the knowledge to make an important decision and that someone will have to make the decision before we can possibly hope to get that knowledge. The function of a scientist as a scientist does not extend into this field. Responsibility for making decisions which are basically indeterminate and must take unassessable factors of human attitudes into account is the proper field of executive authority. The scientist is, however, responsible for seeing that executive authority is fully aware of the assessable factors and of the consequences of different decisions in so far as they can be known, and it is his duty, not only to make this information available at request, but to force it on those in control by all means in his power. There was a saying in the services that the scientist must be "on tap" but not "on top"! Now this, although apparently plausible, contains a very dangerous simplification. The scientist does not claim or want to be on top, but it is not nearly enough to have him merely on tap. In most cases the executive authority

will not be able to see for himself when the scientist should be called in or what questions he should be asked.[1]

The war has brought a terrific increase in our positive means of control of the material environment, culminating in the discovery of the utilisation of atomic energy. It has brought hardly less important advance in the possibilities of human organisation. In both directions, these advances mark at first sight only an acceleration of processes already well in evidence before the war, but it is now becoming more and more obvious that the total magnitude of these changes is producing what is really a new stage in human development—a stage where the conscious integration of human effort is taking the place of development dependent on the unplanned interactions of human wills, often themselves unconsciously motivated. The year 1945 may well be taken to mark an era of ultimate importance greater than that of any transformation since the beginning of human society. Once human society had appeared on this globe, bringing with it the possibility of cumulative tradition and progressive alteration of society itself, the old processes of organic evolution that produced the myriads of species, painfully adapted through natural selection for their mode of life, were completely outpaced in world development. Evolution took millions of years to change things which human beings could do in thousands. Similarly the new scientific, conscious social organisation, once it is fully established, will make the older forms of complex historical development equally obsolete and, at the same time, enlarge the possibilities of material and social advancement of mankind beyond any bounds we can conceive. Naturally, many who have just glimpsed this possibility but who have not understood it—or who have only seen it in terms of the past—shrink from this opportunity and the immense responsibility which it places on man for the conscious direction of his own future. They are in the position of the wild men of the woods of the previous

[1] On one occasion in the war a scientist discovered that an operation was going to be undertaken which, if carried out as planned, would result in certain loss owing to physical conditions. He managed with considerable difficulty to get this recognised and acted on and only later discovered that a report to the same effect presented by his predecessor had been lying in the files of the Command for several months. According to the services code the latter scientist had done his duty. If the matter had been in the field of science he would have established priority of publication, but in the field of action the battle might have been lost because of his nice sense of limitation of the scientist's function.

transformation, who preferred to fend for themselves as had their animal forebears rather than mix in the dangerous and disturbing affairs of human society.

The problem before us now is how to utilise the lessons of the war for peace—not only the lessons that have been outlined above, but the infinitely greater number of lessons which I have had neither the knowledge or the space to deal with, but which are imbedded in the experience of those scientists who have taken an active part in the war effort. Most immediately, there are, of course, the direct technical applications of the scientific advances of the war—in physics, chemistry and medicine; actual factual results of war-gained knowledge and the operation of apparatus developed in the war can be turned to immediate use. I will cite only one example from my own experience in addition to that already mentioned. The operations of the intelligence and the engineering sections in the great variety of theatres in which the war has been fought has led not only to an enormous increase in our geographical knowledge but, even more, to a revolution in geographical methods. Of these, the principal is the use of air photography, the methods of which have been improved out of all recognition during the war and which can be applied immediately to hundreds of problems of academic and economic geography in the peace. Aerial photography makes it possible, for the first time, to hope for a reasonably topographically accurate map of the whole surface of the globe within a few years. Its value for geological and ecological studies is also manifest and its oceanographical value is hardly less. Combined with new methods for measuring atmospheric and sea surface conditions, including waves, we may be able to make enormous advances in our understanding of the interrelations of sea and land. During the war, for practical purposes, investigations on such processes were carried out by means of integrated full-scale and model experiments. We could now take up again the study of erosion and transport of materials where the Victorian amateurs left it and, with the use of explosives, bulldozers and other modern heavy equipment, make the beginning of the study of experimental geology.

What can be done for the science of the earth could be duplicated over nearly every other field of science. The individual scientific research worker has learned through his

war experience that studies which he had hitherto considered impossible were merely impracticable because of lack of resources. The lesson will be wasted unless he is, in peace, enabled to continue to use and even to expand the use of similar resources. Further, the war has given the possibility of quantitative justification of such research. Many scientists may have felt before the war that if they were allowed to do certain research, the community would benefit, but they could never prove it and not enough of them were sure of it to carry conviction. Now in practically every field of science they can point to assured results from investigations properly planned, adequately operated and fully supported in equipment and assistance. The productivity of science is now a measurable factor. The difficulties we foresee in the future are not so much those of lack of support as lack of men to carry out the work.

We know that for any particular project a resolute attack at an adequate scale of effort will bring a fairly certain return; naturally, as we are dealing with the unknown, we cannot always ensure that the object achieved is the object that was at first envisaged, but this does not matter if the object achieved is even statistically—that is, over the average of all ventures—equally valuable. A research into the cure of a particular disease may fail but there is a very high probability that it will provide a cure for some other one or provide an addition to pure or applied science in another field. Knowing this probability of success, however, does not mean opening an indiscriminate number of new crusades into the unknown; by pursuing this or that object with whatever fair hope of success we may be diverting resources from others more important or more promising. The strategy of scientific advance in peace is no less important than it was in war.[1] By a survey of the whole field of the fundamental and applied sciences, and by the analysis of that survey, it should be possible to indicate at least the major directions into which scientific effort might be directed with some idea of their quantitative importance.

Now this raises the old issue of planning and the freedom of science. It is to be hoped that the controversy is dying out as experience begins to show its unreality. The war showed that science can be planned successfully, but it also showed that success was only achieved if the scientists concerned were

[1] See pages 292, 298.

working with full freedom of action and at a job about which they were themselves enthusiastic. The skill of the organiser of science in war was very largely in fitting the jobs to the people and those conditions are not substantially changed in peace. We still have far too few scientists of ability to dream of wasting one of them in directing him to work on something in which he is not vitally interested. Planning does not mean arbitrary dictation from above: the ordering of people to solve this or that specified problem. It does mean that the scientists themselves must get together to find out what their problems are and to set about in a flexible but vigorous way to solve them.

This cannot be done without some organisation and how to evolve it is becoming much clearer in the light of war experience. Many practical people, and some of the more bigoted anti-planners, imagine that the planners wish to attach each particular science to the service of a particular industry —the physicists to the electrical industry, the chemists to the chemical industry, the biologists to agriculture or medicine —but those who have studied the interrelations of science in practice know that it is not as simple as this. Every cumulative discipline of science, with its own tradition, its own grammar and vocabulary, cannot be so isolated and attached, Physics, for instance, not only penetrates all other branches of fundamental science but affects every industry and agriculture and medicine as well. At the other end of the science spectrum, psychology has an equally wide sphere of utility. And the converse is also true. Not a single industry, hardly a branch of any industry, but calls on the service of every discipline of fundamental science—naturally not all to the same extent and some more directly than others. The detailed problem of the organisation of science is the problem of linking these multiple sources to these multiple ends so as to provide the greatest degree of freedom and flexibility. As a provisional solution, opinion is coming round to using an intermediate station as a kind of exchange control between fundamental and applied science—what are coming to be called "background" scientific institutions—such services as have been provided, for instance, by many departments of the National Physical Laboratory. The "background" institution covers a group of sciences on one hand, and industries on the other. For instance, a background institution on silicates would draw mostly on physics,

chemistry and geology and serve the metal, ceramic and building industries as well as civil engineering and agriculture.

In such an organisation, which itself deserves to be scientifically studied and not allowed to grow up haphazardly, a proper balance would have to be maintained between fundamental, background and applied science. All those who realise that there is no simple relation between science and its application will see the necessity for maintaining vigorous, independent, fundamental science. One lesson that the war has taught us is that from every fundamental science may come—as in Radar and the atomic bomb—practicable, usable applications in a time measurable in months; on the other hand the stimulus of practical needs equally rapidly transmitted may provoke the discovery of new problems in fundamental science. To maintain this two-way flow rapidly and effectively is one of the main practical problems of the new organisation of science. The general objective is that of the positive development of scientific ideas in the light of scientifically assessed human requirements.

To achieve it we need, in the first place, a far better system of communications than we have yet enjoyed in peacetime. The system of scientific publication which was in existence before the war was already admittedly completely overloaded and was beginning to break down. Since then it has been largely wrecked as a result of the war. The German scientific publications that have disappeared and the various indexing and summarising functions undertaken in Germany have not been replaced. Meanwhile shortages of paper and labour have reduced the possibilities of exchange of information to a position relatively worse than anything that has existed since the Middle Ages. Even if full recovery is made from these conditions, the major implication of a growing science in an increasingly scientific society will have to be faced. The quantity of ascertainable facts and the rate at which facts are ascertained will continually increase, while the quantity assimilable by any scientific worker is absolutely limited and is already near its limit. The way to solve this problem is clearly to devote some time, money and manpower to a properly recognised system of communications which could be one very largely based on the experience of wartime science. Such a system, however, will not arise of itself. The danger is that scientists will be so preoccupied with their immediate problems

that they will accept inadequate communications and thus hamper their own work in a way which is no less serious because it may not be recognised. The restoration and permanent improvement of scientific communications is one of the legacies that the war has left to science, and one which can be dealt with only by scientists themselves.

The general character of post-war science, particularly that under government control, will differ from pre-war science in one very important respect. The war has shown us that controlled scientific development is an essential part of the full utilisation of scientific discovery; this implies that the material equipment of new governmental establishments should be very much more on factory or semi-factory lines, or, in fact, like those of service establishments or similar establishments, in peace. Emphasis on development will also serve to bring together the scientist and the engineer with mutually valuable results, and will tend to promote a much freer interchange of career, taking the place of the rather rigid demarcation of before the war.

The most balanced and flexible plan for scientific research, however, will not be enough. It will need to be integrated with a positive drive: a technical, biological and social advance carried out with all the resources of the community. That such a task can be achieved has been shown by the experience of the war; but the war has shown also that it is not only possible but absolutely necessary for survival as an advanced community. A national economy, integrated through science and continually advancing by means of scientific research and development, is the basic need of the new era which we are now entering. It implies the expenditure of a much larger proportion of social effort and social resources on science than ever envisaged before.

Those who had considered the advantages that science could bring to society had realised well before the war that the expenditure on science by society was far too small; at that time the total expenditure in this country was something of the order of one-tenth of one per cent of the national income. They could see, and they tried to point out, how the increase of this proportion would bring far more rapid prosperity. In the post-war situation, however, with the leeway of destruction and disorganisation to make up and the far weaker and even

perilous situation of this country, what was desirable has become an absolute necessity, and the proportion to be aimed at must be a much higher one. A committee of the Lord President of the Council is now engaged in assessing the country's requirements of scientific manpower.[1] With all the official data at their command they can obviously make more exact short-term assessments of the needs and possibilities than can ever be made from outside, but it is fairly safe to assume that whatever they recommend it will imply that the fastest attainable rate of increase of scientific manpower will still fall short of our real needs. On the long-term view we must look forward to a fairly rapid transformation in which scientific functions—not necessarily scientific research and development only, but scientific production and scientific administration—will absorb a progressively larger and larger proportion of the population. From one-tenth of one per cent we may advance to involving one, two and possibly ultimately, but in the far distant future, as much as twenty per cent of the population in such activities. This is a logical consequence of the increasing role of human intelligence and consciousness in the management of our society. Long before such a stage is reached, however, the distinction between scientific and non-scientific activity will probably have largely disappeared. Already we require for the proper functioning of our society a certain degree of knowledge of the facts of science and even more of its method on the part of every citizen. The government cannot make decisions, the people cannot carry out the decisions reached, unless they have much fuller understanding than at present of what they are doing.

These considerations necessarily raise the question that is already becoming acute: the position and responsibility of the scientist in society. The recent controversies on the atomic bomb show the degree to which what is essentially a fundamental question of natural science has become the central point of dispute in international politics. This has forced governments and politicians to pay attention to scientists, and at the same time forced scientists to concern themselves as never before with political questions. Rough language has been used against the threat of scientists usurping the functions of the state; scientists on their side have reasserted their responsibility for the maintenance of

[1] This committee has since reported. See *Scientific Manpower* (Cmd. 6824, H.M.S.O., May 1946).

truth and their demands for the removal of restrictions on its spread. On reflection the spheres of responsibility of the scientist and the politician are seen to be distinct, even though they have come to impinge on each other to a greater degree than ever before and will certainly interact to an even greater degree in the future. It is now a fact that no step can be taken on any serious social or political topic, whether it be trade or industry, administration or war, without involving intricate technical and scientific questions, and correspondingly, hardly any discovery of importance can be made in science without important political implications. Now clearly, if the statesman does not understand far more fully than he has ever had to before what is the nature of these discoveries, he will not be able to act reasonably in dealing with them, and conversely, if the scientist knows as little about politics, he will not be able to point out to the statesmen what the consequences of these discoveries are likely to be in the world of affairs. That does not mean that the scientists claim to be the government or to have any special statutory position. The responsibility for final decisions necessarily taken on incomplete knowledge is the business of those selected by the people to act on their behalf. The scientist's job is only to see that the information is as complete as it can possibly be at the time and that research is being adequately carried out to ensure the acquisition of more accurate information.

This naturally implies a more responsible role for the scientist than he was conceived to fill before the war. The conception then was that the scientist in government service was a consultant to be asked definite questions referring to technical matters but not to be concerned with formulating these questions or the policy that resulted from the answers he gave. Such a limited function was already proved to be quite inadequate in the war and will be even more so in peace. In the first place it is self-defeating to limit the subject of inquiry to technical matters; all relevant factors—social, economic and administrative—as much as technical, need to be known before adequate answers can be given. In the second place, an answer given without any relation to the intention for which it was asked is already hopelessly limited and often biased by ignorance. In war it was often more important to know why a question was being asked, than what the question

was. To work effectively in the governmental or industrial machine the trusted scientist must have the fullest access to all sources of information and must be an equal member of all important bodies at which decisions are made. This, not so much because of the importance of his vote but more because the need to be "in the picture" is an essential prerequisite to the formulation and solution of practical problems. This in itself, however, will not be enough. It is also essential that the scientist should have the power and the means to initiate fact-finding research on all matters on which decisions have to be taken. These are perfectly reasonable requirements that have the precedent of the war behind them. They would, of course be much more rapidly granted if, on the other side, Parliament, Government and the Civil Service had more appreciation of the nature of scientific method and the outlines of scientific fact, but we cannot afford to wait for the necessary change in our educational system for this to happen. Actual prejudice apart, it is by no means impossible, through the experience of collaboration between scientists and administrators, to build up a mutual understanding. At the same time organisational changes will be necessary. It is to be hoped that these will be recommended by the Committee on Scientific Manpower. To make administration adequately scientific requires both a stronger central scientific body to deal with general questions, and a more widespread system of scientific advisers in all the departments of state.

The changes proposed here, though radical, we now know are both possible and necessary, for on them depend the successful transition from a pre-scientific and planless economy to a fully planned one with the minimum of loss of efficiency and liberty. It is perhaps not fully realised how much science itself can do in removing the arbitrary and despotic elements which many persons of genuine liberal feeling imagine to be inherent in all planning. Acts are arbitrary in proportion to the lack of knowledge of the situation with which they are made to deal. The more scientific the analysis of the situation, the more possible it is to find a solution which will really answer the need and at the same time be the most acceptable one as demonstrably reasonable. Science, by accepting corporate opinion and reason as its criterion, is itself a democracy: one always open to conviction but not accepting any dictum until it has

been convinced. In so far as science infuses government, it enhances all the democratic elements in it.

All these considerations which have arisen from the first stage of appreciation of the enormous scientific effort that went to the war will no doubt be amplified and reinforced when these lessons are more fully digested; but we have enough already to be able to show how the scientist can turn to advantage, in the welfare of man, the energies and methods which for the past years have gone to his destruction. The war has transformed the world, has left much destruction and many anxieties, but it has also given us a demonstration of the possibility of the rational removal of these evils and their replacement by a better state than we have ever before been able to imagine. That is the major lesson of the war for science.

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THE ATOMIC AGE

INTRODUCTION

AUGUST 1945 marks the beginning of a new era and, let us hope, the end of an old one. It is new in the sense that it revealed the enormous resources available to mankind as a result of profound but remote researches of nuclear physics. It revealed also human capacities for organisation that can transform sheer theory into full-scale actuality in three years. These magnificent potentialities were in fact used to strike down a beaten enemy as a preparatory move to a third world war, and their revelation has plunged the world into a state of anxiety about the future rarely paralleled in history. The first essay in this series was written within a few days of the dropping of the bomb, and before any effective knowledge of the steps leading to the event could be known. Nevertheless it shows the essential dilemma which mankind can now no longer escape, integrated and planned utilisation of science for peace or increasing tension and war. The next, written over a year later, shows the more sober realisation of political and military problems involved. The picture of the atomic age, however, with its promise of boundless power and plenty, was already proving a bitter irony in a world of increasing penury and want. This essay was mainly concerned with countering the hysterical views on atomic warfare. It pointed out that the atomic bomb was not a decisive military weapon but it was essentially a method of slaughter of civilians. The defence against the atomic bomb was not to be thought of in terms of military technique but rather in the preventing of conditions out of which wars arise and, in particular, in preventing the division of the world into two groups with no common humanity. The events of subsequent years have unfortunately only increased this danger but it is one that can be fought and overcome. The last essay in this section is one particularly directed at British readers, pointing out that the only way of saving the economy of Great Britain was by increasing productivity per head, and that this in fact could not be done by financial manipulation, or by reliance on foreign subsidies, but only by full-scale mobilisation and application of science. That lesson is still to be learned.

NEW FRONTIERS OF THE MIND

> This revelation of the secrets of Nature, long mercifully withheld from man, should arouse the most solemn reflections in the mind and conscience of every human being capable of comprehension. We must indeed pray that these awful agencies will be made to conduce to peace among the nations and that instead of wreaking measureless havoc upon the entire globe, they may become a perennial fountain of world prosperity.

Mr. Churchill's words, written in the foreknowledge of the effects of the atomic bomb, are echoed in many millions of minds today. People have been quick to see how the actuality of the atomic bomb has implicitly changed the whole existence of man in this universe. The immediate effects, however horrible, have been decisive in ending the war; but the possibilities of further destructive use are in every man's mind and far more uncertain are the hopes that it may also bring equally untold benefit. These hopes are weak despite official reassurance because, though the people may have little experience of the behaviour of atoms, they have considerable experience of the behaviour of men, corporately and individually. They remember that in the past, science has only been fully deployed in human destruction and this gives a poor augury for the beneficent use of these more powerful forces. The rulers who control these forces are fully aware of this: President Truman in his broadcast said:

> We must constitute outselves trustees of this new force, to prevent its misuse and to turn it into the channels of service to mankind. It is an awful responsibility that has come to us.

The exercise of this trusteeship is, however, greater than can be borne by any government or group of governments. It is one that must be shared with the whole of the human race. Goodwill will not be enough. It needs to be backed by an intelligent appreciation of the possibilities that the mastery of atomic energy gives us, and of the ways in which these possibilities can be realised without disrupting our coal- and oil-based civilisation.

The perfecting of the atomic bomb is only the first impressive practical utilisation of knowledge that appeared almost as

startlingly as the bomb itself in the scientific world of fifty years ago. The discovery of X-rays by Röntgen in 1895, followed by that of radio-activity by Becquerel, was totally unexpected; these discoveries broke up the complacent nineteenth-century determinist physical picture and started a major revolution in scientific theory. There followed the Rutherford theory of the atom with its heavy nucleus and attendant electrons, which showed us a picture of matter very different from our old concrete imaginings; while the quantum theory of Planck and Bohr revealed modes of behaviour of that matter to be even more different from common-sense experience. These ideas led to an almost unbroken sequence of discoveries—neutron, positron, meson—culminating just before the war with the splitting of the isotope of uranium which is the basis for the atomic bomb. The bomb itself is therefore the first large-scale, practical result of fifty years of intense, fundamental scientific activity, but the power of the understanding of nature latent in that scientific work can and will express itself with increasing force and rapidity in many other ways.

What the effect of the use of atomic energy is likely to be on society we can now only dimly see. Those who know most about it are prohibited by military secrecy from making any statement. I can only write about it because it is work in which I have at no time been involved. What is important now, however, is not an accurate presentation of the immediate technical possibilities of the utilisation of processes in atomic nuclei but rather an appreciation of the social effects which such utilisation is bound to produce. The first obvious and incontestable fact is that we have here a concentration of energy of the order of a million times as great as any we have had before. That does not mean, of course, that we have actually increased the available energy in this planet by any perceptible amount as yet. The rarity of the original elements, the practical difficulties of extraction of the active isotopes, and the unavoidable inefficiency of the disintegration process, may make the effective cost per energy unit for many years far greater than that of the more prosaic sources of coal and oil. We may feel reasonably sure, however, that the application of scientific analysis and practical ingenuity will overcome these difficulties in the course of a few years—if the effort made to achieve this result is maintained at the intensity it reached in the prepara-

tion of the atomic bomb. Long before this time, however, there are obvious fields of utilisation for concentrated sources of energy such as the atomic bomb even if considerably more expensive than coal or oil. Such sources would obviously be at a premium in all remote parts of the world where the cost of transport of coal or oil is great and it is there that atomic power will first be cheaper. It does not follow, however, that atomic energy in any case is best transformed into mechanical power. Long before this is achieved on an economic scale, we may be using atomic energy for the production of extremely high temperatures and pressures; for a new metallurgy and ceramics, and in large-scale engineering as a super-blasting agent. Already, in the availability of an enormous variety of radio-active elements in hitherto unthinkable quantities, we have means for the rapid increase of our chemical, biological and medical knowledge out of reach of all previous scientists.

Sooner or later, however, it will be possible to use atomic power economically to provide directly or indirectly for immediate human wants. In the crudest way, such energy can be used to pump water and to make fertiliser, thus both to extend and to intensify agricultural exploitation. At the same time, by increasing the facility of transport, energy can make agricultural products more rapidly available. This means, in effect, that the basic limitation of food supply, already being felt acutely in the world, will be removed.

The discovery of a new source of wealth does not imply its rapid, large scale use. Columbus' landfall did not mean any immediate increase in the means of life of mediaeval Europe, but it did open a new world, and, in time, that new world, with its ever widening frontier, brought an overwhelming increase in human population and standards of life. The development of the atomic bomb is another signal that a new frontier has opened, a frontier more illimitable than a physical frontier of mountain and prairie because it is not tied down to the geographical limitations of this globe but only to the capacities of human intelligence and human ability to co-operate.

Just as, when the New World was opened, the more adventurous of people could not be content with the wise constraints and resignations of the old, so from now on men will have a reasonable impatience at being tied down by the physical

limitations of older methods of production and will demand the most rapid and the most effective development and exploitation of the new powers that science has put into our hands. It is here that lies the way out of the very real horror and apprehension that the atomic bomb has created. Attempts to control this force by secrecy and by limitation are foredoomed to failure. The real way to ensure freedom from fear and suspicion is not such negative control but rapid expansion. Much of the troubles of our time, particularly in advanced countries like the United States, have been attributed to what is called the end of the age of expansion, the closing of the last frontier. With unlimited possibilities for expansion and open frontiers, mutual suspicion and struggles for *Lebensraum* will give way in a new, universal constructive effort full of excitement, uncertainty, hope and promise.

The analogy of the opening of the New World, however, must not be pushed too far. What America gave us was something that people were already acquainted with—lands, forests, mines—only more of them than they had ever dreamed of; our new resources are not in the physical world but come from the systematic and cumulative tradition of science, and their benefits can only be realised by ordered and controlled progress rather than by a further extension of individual and uncoordinated enterprise.

Perhaps as impressive as the atomic bomb itself is the feat of scientific organisation and industrial production that made it possible in the course of three years to go from what was a laboratory experiment, involving hardly more than home-made apparatus and submicroscopic quantities of substance, to a practical release of energy on a scale thousands of times as great as ever before achieved. Social discoveries are intrinsically more important than physical ones. A new way of doing things has an indefinite future not tied to any particular field of knowledge. The overriding need to avoid a similar fate to the one we have inflicted on our enemy has shown what many scientists have long believed: that the potentials of modern science were not being realised for the simple reason that insufficient effort was being put into science. From now on this fact is as inescapable as the splitting of the atom itself.

People had grown so accustomed to the multiplicity of ways in which science was affecting modern life that the majority—

and many scientists—were content with the relatively small-scale and haphazard manner in which scientific research and its application was conducted. That method—or lack of method—is now dead. The object-lesson of the two-billion-dollar expenditure on the atomic bomb, with its integration of scientific, industrial and military organisation, shows what can be achieved if such projects are tackled in a big way. There are hundreds of projects in science, already known to be realisable theoretically, much less spectacular but of comparable importance to the atomic bomb. We have had one example of them already in this war; the development of penicillin, which has saved many times more lives than the atomic bomb has destroyed, or, we hope, will ever destroy. Here again the normal development of fifty years was condensed into two by turning on an adequate effort. Further problems concern the structure of proteins, with their relation to agriculture, food and disease; the problem of controlled genetics, with the production of new and useful species; and the great physiological, psychological problem of the relation of body and mind.

As long as people were content with the pre-uranic scientific progress, that is, as long as people were content with what they knew, a few imaginative scientists who saw the possibilities of the serious and adequate utilisation of science could get no hearing, but now that everybody has seen what the pace can be, they are not going to be content any longer with leaving the realisation of scientific gifts to mankind to their grandchildren or great-grandchildren when they could enjoy them in their own lives. The new era of the atom will also be the era in which the pursuit and application of science will become a major instead of an exceptional human occupation. Put concretely, before the war between one-tenth and one-third of one per cent of the national income of modern industrial states was devoted to scientific research. The war has raised this figure to over one per cent, but a rational appreciation of the newly revealed possibilities of science cannot be content with such a limit. The figure must rise year by year until it reaches stability at some value that we cannot now assess, but may within our own lifetime reach as much as twenty per cent. This implies the recasting of the educational system so as to produce many times the number of scientific workers and at

the same time give every citizen enough scientific knowledge to appreciate the problems of the new age.

The mere increase of scientific activity, however, is not enough; it must be co-ordinated and directed to really worthy tasks. The outer tasks of science—"what needs to be done"—are set by the conditions of society. Sometimes perverse conditions, such as war, require superior methods of destruction, but normally the aim of science should be to enable individual men to realise their inherent possibilities whether expressed in art, in science or in simple human relations. The basic requirements for food, shelter and work must first be met for the present population of the world and for its future increase. How such general directives can be translated into scientific research is a task for the scientists themselves. It needs to be organised—and organised on a world-wide basis. Science cannot be done in holes and corners. Only a combination of the scientists of all the countries of the world, freely interchanging their ideas and persons, can provide sufficient mutual stimulation to ensure a full growth of science. The development of the atom bomb itself required the massed intellects of Britain and America. German and Japanese science, after its perversion by fascism, was not up to the task. Success was achieved by working to a precise and narrow end, but for the general advancement and benefit of mankind the ends are multiple and indefinite. It often takes much greater ingenuity to find out what problems have to be solved than actually to solve them once stated. Even now we can only see a very small fraction of the possible applications of atomic energy. These applications must not be attacked in a haphazard way. Just as in war we had our priorities, so we must have them in peace. The jobs that atomic energy can do immediately are probably gigantic enterprises in remote places. Its use, therefore, must be concentrated where such action is likely to give the greatest human return irrespective of national or individual interests. For example, even now the explosive force of the atom can be used to dig canals, to break open mountain chains, to melt ice barriers and generally to tidy up the awkward parts of the world.

The control of atomic energy, however, which is already promised by President Truman, should be from the start a fully international control, under the guidance in the first place of the United Nations. The maintaining of secrecy on

the principles and processes involved and the limitation of their application to the use of particular nations would be doubly disastrous, partly in slowing down the rate of useful progress, but, far more seriously, in withholding the utilisation of atomic energy on account of mutual suspicion. It was possible to develop the atom bomb in secrecy but under a cloak so wide that it covered hundreds of the most brilliant physicists, chemists and engineers of America and Europe. Far more scientists would have to be brought in for the wider peacetime uses. New and valuable ideas from outside cannot appear effectively under conditions of secrecy. Science needs the widest range of free discussion to develop fruitfully. Sir Henry Dale, President of the Royal Society, has made an impassioned plea for open dealing:

> I believe that the abandonment of any national claim to secrecy about scientific discoveries must be a prerequisite for any kind of international control, such as will obviously be indispensable if we are to use atomic energy to its full value and avoid the final disaster which its misuse might bring.

It is clear that publication and control are indissolubly linked. If we have control without publication, we shall have permanent suspicion and resultant stifling of scientific initiative through secrecy. Such a policy will actually tie up the active sources of energy, which will be kept for war purposes instead of used as fast as they are made. Leading scientists in the world have already recognised this. Sir James Chadwick has said:

> The fundamental principles involved in the atom bomb are so widely known that it is only a matter of time before every country, even without learning the British and United States secrets, develops a similar bomb. I do not think there is any safety in every country having it, but some effort should be made to control its use.

The responsibility is heavy. It must be widely borne. The democratic countries have finished their first task of liberating all countries from domination by reactionary forces. The people of these countries and of the rest of the world must see to it that they do not again pass under a domination of fear created by the very weapons that gave them mastery. They will need all their intelligence and political wisdom from now on to conquer themselves.

From *The Nation*, U.S.A., September 1945

ATOMIC ENERGY AND INTERNATIONAL SECURITY[1]

Atomic Energy in War

THE actual production of the atom bomb is a supreme example of extreme high-pressure research and development carried out under the stress of war. It was apparent to all physicists, and of course particularly apparent to the nuclear physicists, that the moment it had been discovered that a nucleus of uranium 235 could be split in two, not only with the release of energy, but with the release of neutrons capable of splitting more uranium atoms, there was the possibility of a chain of reaction and hence of a bomb. Whether it would work or not in practice was never quite certain until the trial bomb was set off in New Mexico, but in principle it was quite clear to all physicists that it could be done. Consequently in the set-up before the war of anti-fascism and fascism it was necessary for all scientists of goodwill in this country and in the United States to work out the possibilities of using it as a military weapon. The scale and intensity of the development was altogether extraordinary. The expenditure of £500 millions on scientific development on one single project represents probably more than has been spent on the whole of scientific research since the beginning of time. In that you see a prototype of the kind of concentrated scientific industrial organisation that will mark the world of the future. Perhaps more important almost than the fact that it has been found possible to use atomic energy is the fact that we have found a new way of doing new things and proved that it will work. The essence of it is that a purely scientific discovery made just before the war reached full production and utilisation before the end of the war, and effectively in less than two years.

I stress this point because this stage, of course, is only the beginning. I do not know, and very few people do know, what further developments in nuclear reactions have been worked on since the first type of atom bomb used. It is not at all impossible—in fact it has been publicly stated by General

[1] Extracts from a lecture delivered to the Fabian Society in January 1946. The remainder of the lecture consisted of technical expositions of the nature of the fission process and of the destruction caused by atom bombs taken from published sources.

Groves—that far more powerful atom bombs are already being designed. So we must not think of the present atom bombs —and I say this in all seriousness—as the last word in destructiveness; they are really only the first word of the atomic energy age and therefore it is the more important to stop the destructive application of atomic energy at the very beginning of its career.

The Actual Effects of the Atom Bomb

. . . Effectively, what one well-aimed atom bomb produces is the complete destruction of a central city area. I stress that point of city destruction; in other words, one atom bomb carried in one plane does what several thousand bomber raids did in Germany before the surrender. But I would like you also to think of that from both points of view: the atom bomb is a most horrible form of war, but war has not been particularly pleasant for some time, even if it was ever so, and the destruction of Berlin or Cologne is almost as complete, although it took a much longer time to bring it about, as that of Hiroshima and Nagasaki.

You have, therefore, with the atom bomb an intensification of the horrors of war, but you have also the fact, which you must remember from your own recent experience, that destroying cities by itself does not win a war; it did not win the war against Germany, and it did not really win the war against Japan; it gave a chance for the war to end, because as everyone knows, including the Japanese General Staff, the Japanese were beaten before the atom bombs fell.

The atom bomb is the last word in terror weapons. It is a weapon which is most effective against cities, most effective against concentrated populations, and least effective against scattered populations or against widespread armies in the field or navies at sea. There is one necessary scientific aspect of the atom bomb which is not often seen this way round: it is, in a sense, too powerful a weapon. An atomic bomb explodes because, if you bring more than a certain amount of uranium 235 or plutonium together, processes that go on in a slow way in smaller quantities accelerate and the thing goes off. But you cannot have a micro-atom bomb. You cannot have an atom bomb that you could blow up the corner of one house with, like a fifty-kilo bomb in the blitz here. You have got to have a big

one or nothing at all, and that really means that it is the number of atom bombs rather than the size of the atom bomb that counts; in other words it is a weapon adapted for a few big targets and not a weapon adapted for very many small targets. It is a threat to city life; it is consequently a threat to civilisation. We cannot go on living a civilised life under the constant threat of the atom bomb. Nevertheless the atom bomb is not a decisive military weapon and it certainly cannot be used by itself to win wars.

The Problem of the Control of Atomic Energy

I would like to suggest certain perfectly general considerations that must apply to any kind of settlement of the use of atomic energy. The first of that is secrecy.

The scientists who worked on the atom bomb, and all other scientists, have been very perturbed by the danger which the atom bomb represents—not only the direct danger of destruction, or even the secondary danger of international suspicion, but the danger to the whole pursuit of science and to the whole further development of human life on earth. One of the most characteristic things, of course, of the atom bomb up to date is the secrecy that surrounds it. You cannot be secret about the general nature of the bomb, it is too big a weapon. But you can be secret about the details of nuclear reactions or about methods of separating isotopes. The scientists see this web of secrecy growing larger and larger around all their operations, and they see that unless they do something to break it, the whole of science, which depends on international openness, on international communication, will come to an end. All the scientists are in favour of the abolition of restrictions on knowledge of nuclear energy or other similar subjects.

The next point on which we are all agreed, and which is also in the UNO declaration, is that the utilisation of atomic energy should be in the direction of peaceful ends, and not in those of actual or potential war. I stress that point because there are essentially alternative possibilities; that is, fissile material can either be stored as bombs or it can be used for peaceful purposes: you can't as it were burn away uranium 235 and keep it at the same time. Consequently, although there are still—and I do not want you to have any illusions on this

point—many peaceful uses of atomic energy even in conjunction with its war uses—as for example by using energy from a plutonium pile for power production—you could make very much more energy if you did not make bombs.

On these points we are all agreed. When we get beyond them it becomes very much more difficult to determine courses of action. The reason it is more difficult, of course, is that we do not know enough either of the technical or the political facts. The question recently arose as to what are the alternatives for the control of atomic energy. Now, of course, the first alternative—I think we may say already discarded in principle—was the one put forward of the atom bomb as a "sacred trust." The atom bomb as a sacred trust is at its best the control of lethal weapons by one party. The one party concerned may think that he represents goodness and impartial authority and everybody else represents crime, but I think you will recognise that even if that were true it would still be a dangerous policy. In the course of the fight for civil liberties in this country a hundred years ago, one of the things that was insisted on was that the police should not normally be armed with lethal weapons. No one had any aspersion to cast on the police, but on the whole they felt it safer not to allow the police to be armed than to arm them, and that would be still true if there was a recognised international police. But my point is that the arbitrary use of a weapon in the hands of one party is a standing invitation for its use by other parties under the most undesirable conditions of rivalry and secrecy. That was the intolerable situation that lasted all through the autumn of 1945 and that is now being removed by the proposal for the United Nations Atomic Control Commission. But I should say that it depends very much on the pressure of public opinion whether the United Nations Atomic Control Commission is made to work or not. If it does not work, and work quickly, the conditions of suspicion will still remain and will still poison the international atmosphere.[1]

It should be realised when considering the control of atomic

[1] A fuller discussion of these aspects, particularly the discussion of the Soviet Union and American proposals for atomic control and the relation of the Unanimity rule of the United Nations Security Council, are to be found in:

(*a*) Statement issued by the Executive Committee of the Association of Scientific Workers, *International Control of Atomic Energy*, August 1947.

(*b*) P. M. S. Blackett, *Military and Political Consequences of Atomic Energy* (Turnstile Press, 1948).

energy that only nations with a very high industrial and scientific level are likely to do anything serious in the way of making atom bombs. It is a big job—not necessarily as big as it was to start with—and there are only a very few big countries that can afford to do it. Our fear is not an attack by San Salvador on London: that would be suicidal as well as impossible. Therefore if we can get an agreement among the important industrial powers of the world, the question of the control of other parts of the world would not be a serious matter.

. . . The real danger is in the existence of atom bombs in the world at all. As long as they exist, political changes, or some accident or other, may set them off. There is no need to have atom bombs in order to develop nuclear energy: you can develop nuclear energy without making atom bombs, but as long as there are atom bombs in the world they are apples of discord. There is no getting away from the fact that here is a method of destroying cities and civilisations quickly and without warning. An atom bomb in the hands of the international police is not very much better because I do not think there are many international police tasks where the bomb could reasonably be used: against a small country it is superfluous, against a big country it is inconclusive. There are only a limited number of cases where it might be useful, and I do not think public opinion would tolerate it as an international weapon. There is no defence against an atom bomb—there is merely retaliation.

The Political Aspects of Atomic Energy

Now these general considerations as to control lead us back to the really fundamental political aspects. I think all experience of human history has shown us that a technical device, however horrible, does not end war. In itself it simply provokes further developments, some defensive, others even more offensive. All the hopes that were based on the discovery of high explosive did not prevent the high-explosive war. The only way in which a new technical device can bring an end to war is if it stirs actual people into effective political action against war. War is a political act, it is not a technical act, and so the only effective answer to the atom bomb is the condition of peaceful interrelations of nations.

That appears of course an absolutely platitudinous remark, but it is one of those remarks that, although always true, have a habit with technical development of getting truer as time goes on. We have said comparatively cheerfully in the past that the next war—by that I mean this last one—would destroy civilisation. Now it did not destroy all of civilisation, but a great deal of civilisation has been destroyed. We do not like to think of the loss of thirty or forty million people slaughtered in various ways, all of them extremely unpleasant, and of the destruction of about half of the most beautiful cities in Europe. It has not destroyed civilisation, but it is not the kind of thing we want to repeat on a larger scale. Now that means that we have got to put a great deal more popular energy into achieving a peaceful world than was done in the past, and a lot more informed energy. We have got to get rid of the atmosphere of suspicion, the atmosphere of insecurity. The atom bomb has practically repeated in a different and much vaguer form the atmosphere of insecurity that existed before the last war. No one really feels safe in the world with this bomb about: that is why we have got to canalise the popular goodwill to clear it away for good.

The important thing to realise is that a weapon like the atom bomb cannot be used in war unless a previous state of mind has grown up in which the governments of large countries, or, what is ultimately more important, the people of large countries, are capable of thinking that the inhabitants of other large countries belong to a different species, are subhuman. It is because we allowed the fascist and nazi psychology to grow up and spread over Europe that ruthlessness and inhumanity were tolerated even by our own people. The atom bomb is only the culmination of a long series of breaches in custom beginning with the bombardment of open towns, which is something we had protested about before the war. Thus the deliberate destruction of towns, the deliberate attack on civilian populations or the individual slaughter of millions of innocent people, as the Nazis murdered the defenceless Jews, has been allowed to pass with less and less protest. Such things are not happening at this present moment, but we have no guarantee in itself that the old situation will not grow up again.

The one sure protection against the atom bomb is the prevention of any kind of international and inter-racial attitude of

contempt, fear or hatred. We must begin by outlawing the bomb because once we decide that human beings are not to be bombed and slaughtered in hundreds of thousands totally indiscriminately, we shall begin to see that slaughtering them by tens of thousands more or less discriminately is not a particularly good idea either, and we shall be beginning to turn the possibilities of science in a positive instead of a negative way.

I feel, and I think everybody feels in one way or another, that last year was a turning-point in human history, but I do not think any of us, probably, will ever realise, because it will belong to the historian of after our time, quite how big a turning-point it was. Looked at from the scientific developments alone, from the discovery of the utilisation of nuclear energy and from the way in which that discovery was made and the organisation which made it possible, we see that we have added enormously to our potential resources. Physically it is now possible to get rid of the want that has so tormented the world and driven it into wars, brutalities and tyrannies. Further we have a possibility of going forward with a degree of freedom and organisation that we had never imagined before could exist together.

One of the things that strikes a scientist so much about the use of science in the last war is that a thing can be done both freely and in an organised way; democratically, as involving people's wills, and organised in the sense that those wills can be made to work together. The atom bomb is the first example of what can be done by science to give us a great step upwards in the control of the universe. We have only had one change of the same magnitude in all human history—in the discovery of agriculture. Now we have the discovery of a new level of human possibility, and we are at the same time on the social level to make use of it: the two necessarily go together—we couldn't have found it unless we were able to use it. But now we have got both we can move forward to a new age in which mankind will preserve its liberty and enlarge it with knowledge.

Lecture given to the Fabian Society, January 1946, and published in *Left News*, June 1946.

SCIENCE AND THE CRISIS

THE crisis, however urgent its immediate manifestations, is no difficulty which can be overcome by some single heroic effort. It is the practical realisation, forced on us far too late, that the whole economy of this country has been running on a false basis. We have been living too long on the past, on the enterprise of our ancestors in persuading and forcing other people to do our work for us. The predominance of Britain, and of north-west Europe, in the world was bound to disappear anyhow; all that has happened is that it has disappeared a little more quickly owing to our own follies, leaving us in an extremely precarious position, with indigenous food supplies much too small for our inflated population, and therefore more dependent on outside help than any other country in the world. Some of that help we shall probably get from the Dominions, and more doubtfully, and at greater cost, from the United States. But in general the problem we have to face today is how to live on our own resources, that is, on the products of our own country and what can be exchanged for such of these as we can spare.

By paradoxical good fortune, this problem is likely not to be so difficult to solve as it might have been. We have been trying to do far more than we could in the world by the threat of military force, the expense of which has helped to bring us to our present pass. The actual gap between our resources and our needs, once we cease doing this, is one which is within immediate possibility of closing. The very backwardness and inefficiency of British industry gives us a margin for improvement which should be adequate, without our having to strain immediately for any higher degree of efficiency than has already been reached in other countries.

These considerations are cheerful only if we can be sure that the necessary effort to refound our economy will be made, and made in time. Now here there is a very real doubt. One can read the discussions of politicians, economists, industrialists and even trades union leaders, without discovering any apparent consciousness of the absolute need to increase the intrinsic productivity of British industry and agriculture. The total

productivity may, they think, be increased by some general changes in organisation and incentive, by longer hours and harder work. But all these remedies have now been tried for some time without noticeable success. They are all liable to a law of decreasing returns, and indeed may even in a comparatively short time be self-defeating. The cutting down of imports of raw material and food, together with the demand for greatly increased exports, may result only in frenzied ineffective efforts to achieve impossible targets, and in progressive dislocation of industry, growing unemployment and general apathy such as we are witnessing in the Western Zones of Germany.

What has not been realised is the lesson of the development of modern technique, of the transformation of industry which has come about through the application of science in the last twenty years. In this age of the new industrial revolution, the greater part of our industries, as the Working Party reports have shown, are as much ineffective relics of an earlier age as were the hand-looms of a hundred and fifty years ago. Our economy will work and our accounts be balanced only by effecting a transformation of British industry, a transformation of which we can see the general character but the details of which require to be worked out and applied with the utmost intensity and speed. What we have to do, in short, is to produce more from less materials and the same number of men; and we must learn to do this quickly, and, in the early stages at least, to do it without any heavy re-equipping of our industry.

Nevertheless this problem can be solved, and we know from our experience in the war the way to set about solving it. Just because it is an urgent problem and must be solved within months and years rather than decades, it cannot be left to the old evolutionary process of multiple trials and errors, the violent, unhappy, up-and-down methods by which technique progressed throughout the nineteenth century. The problem must be solved both at the centre, where general priorities and main directions of effort must be determined, and at the circumference, in the actual front of industrial and agricultural production, where changes must be made in detail. The reconstruction of Britain must have its strategy as well as its tactics. The great difference between the present position and that in the war is that here the enemy is not concretely embodied and localised. The enemy lies all around us and among us, in

stupidity and vested interest. It is an enemy we cannot defeat without mobilising a wider range of intelligence and purpose than was needed even in the war. In the first instance it is largely an economic problem of managing with existing resources, but it is none the less, and this is the point which has been overlooked hitherto, a technical and scientific one. Our really great resources are not visible: they are potential: they lie in different ways of doing old things, in different uses of materials in substitutes and the saving of waste giving rise to problems—which can only be solved by research and development.

What we need in the first place is a combined economic, technical and scientific General Staff or planning body. At present we only have the economic sector of this, and as yet it lacks both knowledge and power. Under it and closely coordinated with it should be parallel organisations of control and research (such as already exists in the Advisory Committee on Scientific Policy), and, almost equally important, of public information, so that those who have to work the scheme should know what they are working for, should participate in its planning, and should be able to see step by step how they are succeeding in their efforts. Such a planning body should not, like a government, be concerned with immediate day-to-day problems and activities, any more than were the corresponding planning bodies in the war. It should always be looking just one step ahead and would divide its plan according to a series of phases through which the recovery cycle might be expected to run.

There would be a first phase, which we may think of as lasting from now till next spring, of transition and improvisation, in which the main objective would be to keep the machinery of industry going, shutting down inessential industries and concentrating on the best plants. Resources would have to be switched, substituting as far as possible home-produced or new materials for those materials no longer available from abroad —for example, concrete, reinforced and preferably prestressed, might replace timber for many construction purposes, such as floors or roofs; and constructional steel might be saved by altering use specifications. Although necessarily most of the actions taken in this phase could only be economic ones, there would be need for physical research on a large number of key problems

which switching of resources would entail, and there would be an even greater need for operational research for organisational problems. In particular the rationalisation of the whole transport system calls immediately for some such operational research as was used in the war for the destruction of the enemy-operated rail system.

Well before the end of this first phase we might hope to see the general pattern of exchange economy on which we could rely for the next few years, and direct our industrial developments accordingly. This would make possible the next phase of readaptation where, as the result of research carried out in the first phase the more important industries could be physically modified to increase efficiency and diminish waste. We should aim at an all-round improvement in the conversion factor of raw materials, particularly coal, into finished goods. There are, for example, enormous possibilities for economy in the use of coal by better arrangements for burning, for insulation and for the utilisation of waste heat at different stages. All of this could be put into practice according to a prearranged priority plan employing our engineering industry to get the most use out of the smallest quantity of new capital equipment. In industry the pace could be set at this stage by the use of Government factories operated with the best scientific methods of production, analysis and control. In this stage too we may have to consider drastic changes in agriculture and food habits depending on a more immediate human consumption of vegetable products, and science will be needed to see that this can be done without damage to health or morale.

Finally, this phase, which might last a year or two, would give way to the third phase of real reconstruction, with re-equipped industry and agriculture based not on any static pattern but continually growing and being further modified as a result of research and development. It is then that we might expect to see the fruits of new techniques, the use of atomic energy, of industrial oxygen on a large scale, of underground gasification, and of chemical and microbiological production of essential food substances.

We should by no means wish to confine our economic, scientific and technical effort to our own shores. The Commonwealth and Colonies need to be brought in from the start. We need to implement by action the recommendations of the

Empire Science Congress of last year. There will be every reason to go further still. Economic links with our main suppliers and customers in America, Asia, and we hope Eastern Europe, should be supplemented by scientific and technical links. These, using the methods of operational as well as physical research, would aim at an all-round improvement of quality and suitability and at diminution of costs.

A plan along the lines roughly indicated here could certainly cover the immediate gap between the production and consumption in our economy, but it would do much more. It would in fact raise the whole standard of living both materially and culturally. The question is, have we the will or the power to do anything of this sort? As to the first, this will depend largely on the pressure of circumstances. If things get bad enough the engineers and scientists are certain to be called in. The more active and conscious of them have already offered their services, and more will certainly do so. As to the possibility, Government surveys have revealed a very considerable store of scientific and technical ability in the country, but it is at present not being effectively used. An enormous reserve of scientific and engineering talent is tied up in competitive industry and in military research. To liberate it it is necessary at the same time to destroy two illusions, one that the progress of industry requires the existence of a large number of industrial laboratories and development schemes carrying on, in secret, schemes which are very often identical and are in any case much less effectively pursued because of the lack of free discussion. An open pooling of our industrial research and development teams and their distribution along the lines of national priorities would lead to an immediate acceleration of development and give us the possibility of dealing with any short-term difficulties which we are certain to meet. The other illusion is that which leads to spending sixty-five per cent of the Government's contribution to science on military research. Quite apart from its ultimate objective of destruction, most of this is sheer waste. The strength of the country in peace a in war depends on a rapidly developing, fully manned and flexible industry and science. It would undoubtedly be increased by transferring Service laboratories to priority civil needs, and also by switching the very large development contracts for war purposes that are at present tying up industrial laboratories.

The need for action in the scientific and technical field is urgent. Unless the preliminary organisation is set in motion straight away, we will meet more serious crises in the next few months and years again unprepared.

Whether all this will be done depends on how far the people of the country, and particularly the trades unionists, understand how it will serve the real interests of the country.

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POSTSCRIPT, JANUARY 1949

The events that have occurred since this article was written, though already partly foreshadowed in it, have marked the end for the time being of any constructive movement in British economy. Instead of relying on our own efforts the Labour government with the full support of the Conservative party have taken the apparently easy course of relying on U.S. aid through the Marshall Plan. As a result we are committed to an economy aimed at immediate production for export at the expense of capital reconstruction and at the same time we are involved in league with increasingly reactionary governments abroad in preparations for war against the Soviet Union.

This prospect is a disastrous one for science. In the first place it makes nonsense of the one objective mentioned in the article which has been attained, the formation of a Scientific-Economic general staff. For this staff, *The Cabinet Committee on Productivity*, has neither the directive nor the power to reorient the whole of science towards progressive self-subsistence for the country.

There is to be no great move to mobilise scientists and engineers on a great drive to revive British Industry and Agriculture through research and development. On the contrary Sir Henry Tizard has deprecated the value of such research, indicating that it is more important to apply what we know than to find out more, and pinning his faith on psychological research to persuade people to work harder for less real wages. Far from concentrating scientists for long-term work in basic industries, they are to be left dispersed with even greater emphasis on short-term results for the export industries. Worst of all, the fantastic waste of scientific effort for war is not to be reduced, but increased.

This policy spells disaster to British industry and British science, in the long run. Nevertheless the realisation that we are being tied to a fundamentally unstable American economy and being used as pawns in a war for its markets will make its way in spite of all official propaganda to the contrary. War may yet be prevented and a new opportunity occur to use the real natural resources of the country, the resources of intelligence and good will.[1]

[1] A fuller expression of this point of view will be found in my article in *Science for Peace and Socialism* (Birch Books, 1949).

MARXIST STUDIES

INTRODUCTION

THE last section, like the first, deals with more general and fundamental aspects. It contains a series of essays on Marxist subjects, dating from 1931 to the present year. The first short essay marks the important though little noticed impact of Soviet science on Britain, at the History of Science Congress in 1931. The second was written after the first impact of the Nazi attack of 1933 and marks the clear recognition that the essential characters of Fascism were not confined to Germany and Italy, but were a necessary concomitant of capitalism wherever it appeared. The next two essays are appreciations of the great work done by Engels in an interpretation of the natural sciences along scientific lines and the relevance of his ideas to present-day science.

The remaining essays are of a more general and philosophic character, particularly dealing with the scientific aspects of Marxism and showing how Marxism did not take the place of the natural sciences, but included them and showed their significance in the wider content of human and cosmic evolution. It is through Marxism that the unity of the sciences among themselves and their further unity with social processes can best be understood. The final essay is an attempt to assess, after a hundred years, the intellectual and philosophical effect of the Communist Manifesto.

SCIENCE AND SOCIETY

LAST week there took place in London the Second International Congress of the History of Science and Technology. It did not attract much attention in the Press precisely for the reason that it most deserved it. It might have been an ordinary international congress, for the exchange of information, mutual

edification and mild publicity. The appearance of the Soviet delegation changed all that somewhat abruptly, and made it instead the most important meeting of ideas that has occurred since the Revolution. What we know about the Russian experiment is derived from incomplete or mendacious accounts in the Press and the reports of more or less unqualified travellers; of the ideas which are the driving force behind it we know little or nothing. Here was for the first time an authoritative and representative body, executives and scientists, Bukharin, Joffe, Vavilov, Hessen, Rubinstein and Colman, Zavadovsky and Mitkewich, prepared to expound and debate their conception of the universe and their schemes of action with the bourgeois intellectuals of the West.

Already in the programme of the Congress, drawn up under the inspiration of its president, Dr. Singer, there appeared a distinct tendency towards the position that the Russians had assumed dogmatically from the beginning. The old conception of the history of science, the bare enumeration of discoveries and inventions, the telling of lives and deeds of great men, and the drawing up of the genealogical tree of present knowledge, is now seen as a partial though necessary basis for the study of the interaction of science with economics and politics, with religion, art and industry, throughout the whole course of history, not least in the present. The first morning session discussed this very point—"The Sciences as an Integral Part of General Historical Study." Professor G. N. Clark and Professor A. V. Hill, the one as historian, the other as scientist, declaimed against the limitation of history, as taught in schools and universities, to purely political and military history. Kings, parliaments, battles and treaties are but a proof of the collective stupidity of man. More emphasis should be given to those intellectual advances which have made him superior to the maleficent forces of the outer world, and in which his true greatness lies. Colman and Rubinstein objected to this as carrying too far the reaction to traditional history. To celebrate Newton and Darwin instead of Marlborough and Lincoln as the great minds who lifted man out of ignorance into light was to make an opposite error almost as great as the first. It was the age that formed and found the man rather than the man who made the age. Political and intellectual history are two branches of economic history, particularly that of the control

of production. What was impressive about this discussion was not so much the antithesis of the importance of the individual and the mass—that we were familiar enough with—but the totally different attitude displayed towards the history of science. It was quite apparent that on the English side both historians and scientists were, as far as the history of science was concerned, essentially amateurs. Primarily each pursued his own branch, with occasional attempts at correlating them. The Russians proceeded quite differently. The history of science was plainly vitally important to them; it was not only an academic study but a guide to action. They proceeded integrally with the social aspect dominant, in the past as in the present. There could be no effective argument. They had a point of view, right or wrong; the others had never thought it necessary to acquire one.

The second session aroused the most interest and excitement. The relation of the physical and biological sciences has often been discussed in recent years and always leads to the same conflict between vitalism and materialism, between the old, who cling to the idea of "life," and the young, who are more concerned with measuring and controlling its processes. Professors J. S. Haldane and E. S. Russel both complained of the ultimate impossibility of the mechanistic theory or the analytic study of life to give them the kind of understanding they wanted, while Dr. Needham and Professor Hogben claimed that by the application of mathematical and physical science to biology and in no other way could they get any information about living things at all. Professor Hogben's speech was of a brilliant and devastating eloquence but in his logical destruction of vitalist views a new note crept in. These questions could no longer be treated as purely scientific or philosophic questions, they were political questions in disguise. Just as the growing free thought of English Dissent in the eighteenth century had been frightened into emotional Methodism by the French Revolution, so the mechanistic Darwinism of the triumphant capitalism of the nineteenth century was being frightened by the growing strength of the Soviet Union into the popular scientific mysticism of Jeans and Eddington, of J. S. Haldane and Julian Huxley.

Here the Russians took an intermediate attitude. Certainly they are not naïve materialists; their organic view of society

precludes them from seeing a living thing as simply decomposable into independent parts, but more strongly still do they repudiate the contemplative and reverent impossibilism of the true organicist. And yet out of the polemic there already appear the first signs of a general agreement. The new quantum mechanics with its insistence on the interdependence of the parts and the whole supplies a model for the phenomena of living matter, and whether this model is mystical or materialistic does not affect its practical utility for the interpretation and control of life.

After such a day the third session was bound to be somewhat of an anticlimax. Everyone agreed that pure and applied science were interdependent. The English emphasised the growing appreciation of the debt of industry and public services while the Russians pointed out the converse. To them, the development of pure science is dependent on that of economics and technics both for the problems they present it with and for the means provided for their experimental study. As an example Professor Joffe emphasised the dependence of present-day atomic physics on the development of commercial wireless and electrotechnics. This argument was continued in a rushed and almost rowdy special session on the last day, which was entirely devoted to the Soviet delegates. Here they attempted, quite hopelessly in the time available, to give substantial justification of their general attitude. However, from their published papers we can see that two lines of argument were intended.

The first demonstration was a historical analysis of actual discovery, particularly detailed in the case of Newton, showing the dependence of his thought firstly on the dominant technical problems of the day in navigation, ballistics and metallurgy, and secondly on the current political and religious controversy. Newton's work represents the scientific analogue of the Anglican compromise standing between the Aristotelianism of Rome and the rank materialism of Overton and the Levellers. Thus, even mathematics becomes in a sense permeated with political and economic influences. This attack on the last sanctuary of pure science called forth a solitary protest from Professor Wolf, whose voice, with that of Sir William Whetham in the first session, were the only ones raised in defence of the academic ideal.

The second demonstration is that of the close relation between science and technology in the planned industry of the Soviet Union. In this relation both gain—not only industry from science through the rapid solutions of problems and the suggestions of new processes, but science gains from industry by the vastly greater funds at its disposal, by its more coherent organisation, by the possibility of experiments on large-scale factory lines, but most of all by the inspiration from the problems of actual practice and by the intellectual co-operation of the workers. The most convincing example of this was provided by Professor Vavilov, who with his two thousand co-workers has by field expeditions and experiments established the seven chief centres of distribution of cultivated plants in the world. This work will not only be of great assistance to a rational agriculture but at the same time throws light on purely botanical problems and on the fascinating quest of the origin of civilisation.

It will take some time to appreciate the effect of this first contact between the thought of the U.S.S.R. and the Western world. In an immediate sense it was a failure. The time was too short, the gulf between the points of view too great, for there to be any real understanding. The Russians came in a phalanx uniformly armed with Marxian dialectic, but they met no ordered opposition, but instead an undisciplined host, unprepared and armed with ill-assorted individual philosophies. There was no defence, but the victory was unreal. The strength of the spirit of bourgeois science, particularly in England, lies in its avoidance of explicit statement. It is a comprehensive attitude which cannot be effectively attacked because it is so genuinely implicit and unconscious. And so the Russians produced but little effect. Their appeal to the dialectic, to the writings of Marx and Engels, instead of impressing their audience, disposed them not to listen to the arguments which followed, with the feeling that anything so ungentlemanly and doctrinaire had best be politely ignored.

Yet to ignore it permanently would be for our own sakes a great mistake. The more intelligent of bourgeois scientists realise the appalling inefficiency of science at the present time, tied as it is to academic and impoverished universities and to secretive and competitive industries and national governments. This is not only in its applications, which are only fully effective

when noxious, but in its intellectual processes themselves. They tolerate this inefficiency because they see no way out of it, but slow spontaneous organisation, and because it is taken as the price of a dearly cherished individual liberty of thought. In contrast to this we have now a rapidly growing relatively efficient mechanised science. There are in the U.S.S.R. 850 linked research institutes and 40,000 research workers. This forces on us two insistent questions, as to whether our individualist methods in science are not as obsolete and as effectively doomed as was the craftsmanship of the Middle Ages, and whether after all they are worth saving. Is it better to be intellectually free but socially totally ineffective or to become a component part of a system where knowledge and action are joined for one common social purpose?

From *The Spectator*, July 1931

THE SCIENTIST AND THE WORLD TODAY

Analysis and Programme

EXPLANATORY NOTE.—This is not an essay or pamphlet in the usual sense: the subject is too big for dealing with in continuous narrative in this scale. Instead an argument is presented in condensed form as a list of statements and indications, the full content of which is implicit and derived from the reader's own experience and knowledge. The numbers serve to indicate in their main sequence the trend of the argument; the minor sequences indicate subordinate branches. I cannot gauge the value of this partial break from literary tradition. I find most books to contain a disproportionate number of words to ideas. The continuous flow of narrative certainly makes them easier to read but does not force thought on the reader and obscures the mutual relationships and relative importance of the parts.

The trend of the argument is neither simply deductive nor simply analytical. It proceeds from the scientist's awareness [1] of the immediate and compelling dangers of war and fascism [2] to an analysis of their causes [3], a consideration of desirable alternatives [4], the means [5] by which they cannot

and can be obtained, and finally to the possibility of immediate and practical action [6].

There is no claim for originality of theses or solutions; the only advantage is a clarity of presentation which should make it impossible to evade issues and to bring out precisely at what point any reader refuses to follow the argument further.

1] THE SCIENTIST AND SOCIETY.—Since the fifteenth century the scientists individually and collectively have played a unique and increasingly important part in the characteristic transformation of primitive agricultural society, essentially complete in 2000 B.C., to the mechanical chemical society of today. The future development of such society is impossible without the active co-operation of scientists.

1.1] This development has proceeded up till now largely unconsciously as far as individual scientists were concerned, particularly since the endowment of science and the growth of specialisation in the nineteenth century. In so far as scientists had a political outlook at all, it was bounded by the implicit belief that the utilisation of science could only be beneficent, that cultural and mechanical progress were equivalent and would continue automatically.

1.2] The disasters and dislocations of the twentieth century, beginning with the war and recurring in multiple economic and political forms in the crisis of 1929, combine to destroy this easy picture of the world. The scientist, in particular, cannot help seeing that in some way these disasters are a result of science quite as much as the general prosperity that was hoped for.

1.21] The incidence of this awareness is not uniform. Individuals, according to the relative strength of their political and other interests, begin to notice the dangers at different times; they have, so to speak, different coefficients of political consciousness. The total effect is independent of these differences; a state of greater political strain is bound to bring more people into political activity. The extremes are stable good government where private life and work occupy all but a residuum of natural politicians, and revolution where private life and work are impossible and everyone is a politician.

1.3] The coefficient of political consciousness of scientists is low because socially and economically they are a particularly sheltered section of the middle class and are psychologically

selected for an absorbing interest in special problems. However, even scientists in this country have been affected by the cuts and unemployment of the economic crisis and cannot avoid the spectacle of the effects of political action on their colleagues in Germany.

1.4] Merely to see that the world is not the pleasant place it was imagined to be is not enough, particularly if the awareness is sudden. The immediate and threatening dangers are only symptoms. They can only be apprehended in their true significance by a political education which most scientists lack. The more natural tendency is to look for some delusive immediate solution, such as social credit or liberal fascism.

1.5] Against these instinctive tendencies scientists have certain protections. Intellectually they are implicitly acquainted with the scientific method and ideally they belong to a powerful body of tradition, of reason, welfare and liberty. Both these, in so far as they are soundly apprehended, should guard them against the grosser follies of anti-intellectualism and barbarism which, as recent events have shown, can so easily sweep away the effects of centuries of middle-class culture. But more than this is needed. In the first place, an analysis, as well as an awareness of the immediate dangers, viewed in the light of the tradition of scientific culture.

2] THE IMMEDIATE DANGERS.—War, cultural and economic reaction.

2.1] *War.* The actuality of this danger and its extent need not be stressed. The scientific tradition stands dead against war as the worst perversion of science. But this is more an ineffectual moral than an effective practical attitude. For science and scientists have profited much from war and war preparations. Consequently there is a tendency to deplore war while admitting its inevitability and doing nothing to prevent it. If there was a genuine objection to war it should extend at least to its immediate antecedents.

2.11] All political and economic policies which, without ostensibly aimed at producing war, make it in fact inevitable after a longer or shorter period. This applies to all forms of nationalist or imperialist policy which use implicit threats of force to secure economic advantage. The gamblers in prestige have to show their cards sooner or later, and that is *war.*

2.12] All ideologies glorifying war, directly as aggressive

nationalism, or indirectly as defensive patriotism, or beneficent administrative imperialism. Scientists are particularly likely to be drawn in to the support of the last because of the scope it offers for their own activities.

2.13] All material preparations for war. Accumulation and development of armaments by governments. All research on armaments, offensive or defensive. Any economic interest direct or indirect in armaments. It is a mistake to confine this to the interests of private armament firms. Even without them the activity of government arsenals would lead to greater profits in the metal and chemical trades.

2.14] It is plain that opposition to the antecedents of war involves opposition to much that is fundamental in the structure and ideas of the capitalist state. Therefore such opposition to war is effectively opposition to the state, particularly one's own state, in so far as it is an organ for war. This is the essential liberal formula towards war. Its insufficiency will appear later.

2.2] *Cultural Reaction.*—This is easier to recognise than to define, but in its clearest exposition in Italian or German fascism it represents a conscious and deliberate turning away from the tradition of liberalism and in its most extreme forms an assumption of what is imagined to be the barbarism of a pre-intellectual age. As most of the practical expressions of liberalism in human welfare and education are due to the influence of science, those most affected after the immediate victims are the scientists who see the efforts of centuries purposely destroyed.

2.21] *Illiberalism.*—The doctrine of implicit obedience to a presumably divinely indicated leader of a state to which all allegiance is due, with the consequent destruction of all democratic forms.

2.22] *Militarism.*—The idea of a specially favoured nation or race expected to show its superiority in war and later achieve dominance over inferior breeds. In old and successful empires like ours the offensive aspect need not be stressed.

2.23] *Reactionary Domesticity.*—Anti-feminism, forcing the women back into the homes to breed large numbers of children in a dogmatic religious atmosphere. Religion, whether Catholic or Protestant, has here definitely shown its compatibility with fascism.

2.24] *Reaction in Education.*—Introduction of ideas of obedience

and militarism. Distortion of historic fact in national interest. Diversion of scientific research to military ends. Suppression of the psychological sciences.

2.25] *Reactionary Penal Legislature.*—This is the most barbarous regression, because it goes back beyond the eighteenth century to the vindictive theory of punishment, including torture. It is particularly important as the number of prisoners is increased many times. Its only advantage is that it destroys the hypocrisy of an impartial justice.

2.26] *Reaction in Literature, Art and Morals.*—Censorship of modern and past work aimed at socialistic, international and pacifist tendencies. General anti-intellectual attitude and tendency towards mystical enthusiasm.

2.27] *The Doctrine of Racial Superiority.*—This has a double aspect justifying exploitation of inferior races and concealing exploitation of the workers of superior race in the exploiting country. In its special form of anti-semitism the race doctrine strikes directly at science and intellectual life.

2.28] It is not necessary to go to Fascist Italy or Nazi Germany to meet all these tendencies in action. In England they are openly advocated by many conservatives and widely practised, though somewhat hypocritically, in schools and homes. To see them in their full glory it is necessary to go to democratic dominions like South Africa.

2.29] *Cultural Reaction is not a Blind Tendency.*—While not touching the essential processes of capitalist production for profit it aims at making this possible in an altered world by inducing docility in the workers, partly by force and partly by the illusion of class collaboration in a national community.

2.3] *Economic Reaction.*—General fall of standard of living in all capitalist countries.

2.31] *Economic Nationalism and Mercantilism.*—This is a logical development of monopoly capitalism, but in its international aspect is a leading cause of the breakdown of capitalism. The advantage of improved technique, due to science being more than compensated by uneconomic location and the uncertainty of international trading.

2.32] *Anti-mechanism.*—This is largely a fascist diversion aimed at gaining support of masters and workers in backward industries. There is no intention of abandoning heavy industry where it is profitable. However, by lengthening hours and

lowering wages greater profits may be got in certain cases out of primitive industry and thus unemployment may be reduced at the expense of the general standard of living. This is particularly true of the exploitation of colonial peoples.

2.33] *Primitive Agriculture*.—Insistence on retaining primitive methods of agriculture in the interest of property rights and the maintenance of a body of ignorant agricultural supporters is a cornerstone of reaction, fascist or otherwise. Combined with tariff and quota policy it means high food prices to the consumer, wasteful overproduction and destruction of food, and large profits for monopolistic food-distributing enterprises.

2.34] *Blocking by Economy Measures of Social Services*.—Housing, medicine, maternity, children's welfare. This is simple torture and murder as shown by health and mortality statistics in the interests of preserving a capitalism that cannot support itself.

2.4] This catalogue of folly and misery is what the immediate future offers. It is particularly galling to the scientist who knows the immense possibility of increased welfare for all.

2.41] But it affects the scientists still more directly, for in so far as fascist reaction dominates, science is finished. Cultural reaction destroys the ideals of science and its essential international character while perverting it in the service of war. Economic reaction removes its material support and dries up the stream of future students by curtailing education.

2.42] This wave of reaction appears to the scientist as a wanton and inexplicable turning away from the liberal tradition of progress.

2.43] But it is anything but wanton. Fascist reaction is, in fact, an attempt to escape from the intolerable conditions produced unwittingly by liberalism and by science. Not to understand this is merely to waste efforts in denouncing the symptoms, fascism and reaction, without offering an alternative better than the *status quo* which gives rise to them. This is the essential futility of the Liberal and Labour position. To understand and check the dangers of the future it is necessary to look for them in their latent form in the present.

3] THE LATENT DANGERS.—These are essentially economic. The world system of production and distribution is plainly in a state of chronic instability and decay. This has got so far as even to be admitted by executive supporters of the present

system—MacDonald, Mussolini, Roosevelt. But these as well as their liberal supporters do not accept the instability as inherent in spite of repeated efforts at amelioration which have only resulted in deepening the crisis.

3.1] *Instability of Production and Distribution.*—Boom and slump are logical consequences of production for profit. In spite of the hardship they inflict they do not endanger the system as long as there is a possibility of market expansion, and as long as profit-making enterprises are not too large. But once the market is divided by spheres of preferential exploitation—the empires of the late nineteenth century—and once monopoly enterprises become established, this factor of safety disappeared and trade crises came to endanger the whole system. This danger produces attempted remedies even more disastrous.

3.2] *Economic Nationalism* is an attempt to protect monopolist enterprise by using state powers—tariffs, quotas. Private capitalism, monopoly capitalism, imperialism, economic nationalism are natural and inevitable developments of the practice of production for profit. Economic nationalism exacerbates crises leading to:

3.3] *International anarchy* of production and economic warfare. Currencies, debts, prices and wages in different countries are pitted against each other. The immediate result is unemployment, starvation and fantastic waste. (5,000,000 pigs destroyed in U.S.A.)

3.4] *Economic warfare* leading directly to actual war. Trade agreements, debt settlements, treaties can only be maintained by the favoured party by force or threats of force. These threats must be supported by a material show of strength, and this is reinforced by the fictitious prosperity and real profits to be obtained by the manufacture of armaments.

3.5] Inside the several capitalist states the effect of economic depression and unemployment has led to a general feeling of hopelessness and insecurity. This demoralisation expresses itself partly in crime, partly in mystical religious movements, both breeding grounds for messianic fascism.

There is plainly no future in capitalism, and it is difficult even for its Liberal and Labour supporters to raise any enthusiasm for its continuance. Fascism is the supreme attempt to use this discontent and disillusion to fasten firmly on the people an aggravated form of capitalism. It promises to *do* some-

thing. However intolerable and dangerous fascism is, people will accept it unless they can be shown something better.

4] For the scientist it is no longer a question of getting on with his work and leaving the rest to progress. It is the same blind progress—the following of monetary advantages wherever they lead—that has brought us to our present position. It is time to determine consciously what we need, what are the difficulties in the way, and what can be done to remove them. In the first place it is worth enumerating some necessary conditions for a tolerable world, and their connections and implications.

4.1] *World Economy.*—An interchange of products and services on a world scale is necessary to maximalise welfare. This is a logical consequence of large-scale mechanical and agricultural production. It must be a planned economy, or it would be liable to terrible dislocations as the events of the last few years show. The apparent short cut of closed national or imperial economies is delusory: it leads to international economic chaos and war. But world economy is blocked by existing nationalism. Consequently to administer it we need:

4.2] *World State* making economic nationalism and war impossible, but preserving nationalities as cultural units only. Both these possibilities are incompatible with the present form of effective political control by producers for profit. This in itself can hardly be considered desirable, so we shall require further:

4.3] *Classless Community.*—This is the most difficult to obtain, but the most fundamental. It is not human acquisitiveness in general, but differential acquisitiveness expressed in a class-stratified society, that automatically brings us to our present position. Differential social advantages protected by law and custom must disappear. There must be effective equality of opportunity for service, not for acquisition.

4.4] *Science for Welfare.*—With the security and opportunity guaranteed by these three conditions it will be for the first time possible to use science for welfare. We have not as yet accomplished the first step in this direction:

4.41] Not to produce and reproduce known evils—miseducation, superstition, crime, disease, starvation and war.

4.42] To use available knowledge to remedy known evils; economy and superstition stand in the way of this at present.

4.43] Adequate endowment and intelligent direction of research for the remedy of known evils.

4.44] Further research for hidden evils, and for the discovery of means for better living.

4.5] The whole of this programme is immediately technically possible. Yet it appears quite fantastic as practical politics. This is because in the first place the present evils are far too patiently endured, and in the second that many of the people, particularly scientists who know how to change them, refuse to face the very real difficulties involved.

5] SOLUTIONS.—

5.1] It is plainly impossible to look for solutions inside the framework of pure liberal capitalism. Simple capitalism no longer exists anywhere in the world. What we have instead is broken-down capitalism patched up with a mass of emergency restrictions and subsidies tangled in bureaucratic organisations.

5.2] The system has broken down as the result of its characteristic feature of production for profit. But in remodelling it is just this feature that is being retained at all costs. Let us have planned economy, socialism even, but let no property-owner lose a penny or no government any of its military prestige! Such policies are not solutions, but aggravations of the present instability and, whether proposed by Conservative, Liberal, or Labour politicians, are only shamefaced versions of fascism. Even in America where the policy of mitigated capitalism is being pushed with the greatest vigour, it will only succeed by failing in its ostensible purpose of raising real wages.

5.3] No one really believes in this half-and-half capitalism. Scientists and technicians increasingly recognise that the only solution is the radical solution of the U.S.S.R. The logic of orderly production for welfare has there shown its value in practice even when weighted against a series of apparently insuperable disadvantages: The ruin of war, the interventions, the lack of capital, the lack of administrators and technicians, the backwardness of industry, the inert and conservative peasantry, the suspicious hostility of other powers, the permanent threat of invasion. The U.S.S.R. is alone among the nations moving on. And not only economically, but culturally. It is no accident that Russia provides the antithesis to the whole catalogue of cultural reaction represented by fascism. In science, in education, in religion, in the family, in the prisons,

the U.S.S.R. gives practical embodiment to the progressive ideas of the nineteenth and twentieth centuries. The communists are the heirs and the only defenders of the liberal tradition.

5.4] There can be no doubt that the achievement of the U.S.S.R. is the nearest practical embodiment of the ideals for which scientists work. But this admission has implications which are very difficult to face. Before achievement was possible in the U.S.S.R., and before it could be possible anywhere else, the power of capitalism had first to be broken, and broken by the power of the workers. The sacrilege was not revolution, but expropriation of capital and the extinction of production for profit.

Scientists are so rooted in their class that in the main, rather than face this, they will give up their liberal traditions and wait resignedly for the reaction of fascism. In this they betray their traditions and are not even sure of saving their pockets or their skins. This is not of course in the least how it appears to them, but is the reality behind the vague hopes of amelioration without unpleasantness offered by the Liberal and Labour parties.

6] WHAT CAN BE DONE. The movement of events has, however, brought more and more scientists to realise the necessity of the mode of transition as well as the desirability of the end. This recognition remains academic unless it can be translated into appropriate action. What can be done here and now to assist in a task that needs must be difficult and long drawn out?

6.1] The first step is the acquisition of effective knowledge. Without an understanding of the working of economic or political factors in the present world, goodwill, idealism and ability can easily be diverted into fantastic currency schemes, national planning, even to fascism itself. This knowledge can never be deep or detailed enough, but also it cannot be only academic. Effective knowledge can only be obtained through active co-operation in current movements.

6.2] *Organisation.*—At the moment there is no effective organisation of scientists. The Association of Scientific Workers is poorly supported mainly because there seemed no general issue on which scientists could unite. By now, however, scientists are visibly uneasy on the questions of war, unemployment and fascism, echoes of which have even reached the

British Association. This uneasiness has to be crystallised in discussion and organisation.

Individually scientists are weak and easily intimidated; once organised their key position in all modern states would make them a powerful force.

6.3] While the organisation is growing there is scope for activity in only war and anti-fascist movements. It is by implacable opposition to war and fascism in all forms, particularly in his own country, that the scientist can show that he really believes in his tradition and is prepared to fight and suffer for it.

6.4] Scientists are in an anomalous position. Socially they belong to the capitalists, culturally to the workers. The workers' state needs science more than any other. The transition would be easier and progress more rapid if the bond between worker and scientist was already effective before it is achieved. Co-operation by the scientist in working-class movements removes his isolation and provides a firm basis of political support.

In this way, and only in this way, can the scientist come to understand the full reality of the present situation and the practicability of the means of altering it.

From *Cambridge Left*, Winter 1933

ENGELS AND SCIENCE

IF Engels had not been the constant companion in arms of Marx in the revolutionary struggles of the nineteenth century, there is no doubt that he would be remembered chiefly as one of the foremost scientist-philosophers of the century. It was an ironical tribute paid to the correctness of his views as to the relations between politics and ideology that he suffered complete neglect from the scientists of the Victorian age. But time now has taken its revenge, and Engels' contemporary views on nineteenth-century science seem to us now in the twentieth far more fresh and filled with understanding than those of the professional philosophers of science of his day, who for the most part are completely forgotten, while the few that linger

on, such as Lange and Herbert Spencer, are only quoted as examples of the limitations of their times.

Engels as a Scientist

It is often said by those anti-Marxists who never trouble to read the original writings that the scientific knowledge of Marx and Engels was superficial; that Engels, for instance, sought in later life for scientific justification for the dialectical laws that Marx had introduced into economics. This is a complete misreading of the facts. Engels' interest in and knowledge of science was deep and early. It ran through all his philosophical and political studies. In an essay as early as 1843 (quoted in the *Marx-Engels Selected Correspondence*, p. 33), he shows a grasp of the fundamental connection between science and productivity that was to run through all his later work:

> . . . yet there still remains a third factor—which never counts for anything with the economists, it is true—namely, science and the advance of science is as limitless and at least as rapid as that of population. How much of the progress of agriculture in this century is due to chemistry alone, and indeed to two men alone —Sir Humphry Davy and Justus Liebig? But science multiplies itself at least as much as population: population increases in relation to the number of the last generation; science advances in relation to the total amount of knowledge bequeathed to it by the last generation, and therefore under the most ordinary conditions in geometrical progression too—and what is impossible for science?

Engels to the very end of his life not only made use of the science he had learnt at the university, but kept up with extraordinary keenness and understanding his interest in the scientific discoveries of his times. Far from being prejudiced by any preconceived theories, he was more open to accepting new ideas than were the professional scientists. In a letter to Marx in 1858 he shows himself prepared to accept beforehand the idea of transformation of species which Darwin was to publish in the next year (*Marx-Engels Correspondence*, p. 114). In one passage he almost hints at the idea of evolution, derived from the Hegelian idea of transformation of quantity into quality:

> So much is certain; comparative physiology gives one a withering contempt for the idealistic exaltation of man over the

> other animals. At every step one bumps up against the most complete uniformity of structure with the rest of the mammals, and in its main features this uniformity extends to all vertebrates and even—less clearly—to insects, crustaceans, earthworms, etc. The Hegelian business of the qualitative leap in the quantitative series is also very fine here.

A few months later, when Darwin's *Origin of Species* appeared, Engels and Marx together acclaim it as putting an end to teleology in the natural sciences (*Marx-Engels Correspondence*, Letter 49). If we contrast this attitude to that of the official philosopher of science, the physicist Whewell, a great derider of Hegel, who was at the same time urging that Darwin's book should not be accepted by Trinity College Library, we can measure the greater breadth and penetration which their philosophical outlook had given to Marx and Engels. It was the same with all the significant ideas which science was developing. The great physical and chemical advances of the century, particularly the conservation of energy and the development of organic chemistry, were also recognised and carefully studied by Marx and Engels. In his approach to science, Engels cannot be said to have been an amateur. In Manchester, where he spent most of his life, there was a very lively scientific life with which he freely mixed, and, in particular, he had as his intimate friend Karl Schorlemmer, the first communist Fellow of the Royal Society, and one of the most distinguished chemists of his time.

The Dialectical Approach to Science

From the start Engels was able to unify his conceptions of science in such a way that he could naturally assimilate new developments as they appeared, and that without any of the wilder flights of such scientific philosophers as Haeckel or Herbert Spencer, but in an extremely sane and balanced way. The secret of this power lies in the materialist dialectic which he used in his analysis of the results of science. It was from Hegel that he learnt to appreciate, not things, but processes, and he always looked at the position which science had reached at any time in relation to its historical background. This is clearly seen in his essay on Feuerbach, where he traces the history of materialist philosophy in relation to the development

of science and productive methods. For instance, on p. 33 of *Feuerbach* he says:

> But during this long period from Descartes to Hegel and from Hobbes to Feuerbach, the philosophers were by no means impelled, as they thought they were, solely by the force of pure reason. On the contrary. What really pushed them forward was the powerful and ever more rapidly onrushing progress of natural science and industry. Among the materialists this was plain on the surface, but the idealist systems also filled themselves more and more with a materialist content and attempted pantheistically to reconcile the antithesis between mind and matter. Thus, ultimately, the Hegelian system represents merely a materialism idealistically turned upside down in method and content. . . . (p. 36). The materialism of this last century was predominantly mechanical, because at that time, of all natural sciences, mechanics and indeed only the mechanics of solid bodies—celestial and terrestial—in short, the mechanics of gravity, had come to any definite close. Chemistry at that time existed only in its infantile, phlogistic form. Biology still lay in swaddling clothes; vegetable and animal organisms had been only roughly examined and were explained as the result of purely mechanical causes. As the animal was to Descartes, so was man a machine to the materialists of the eighteenth century. This exclusive application of the standards of mechanics to processes of a chemical and organic nature—in which processes, it is true, the laws of mechanics are also valid, but are pushed into the background by other and higher laws—constitutes a specific but at that time inevitable limitation of classical French materialism.
>
> The second specific limitation of this materialism lay in its inability to comprehend the universe as a process—as matter developing in an historical process. This was in accordance with the level of the natural science of that time, and with the metaphysical, i.e. anti-dialectical manner of philosophising connected with it. Nature, it was known, was in constant motion. But according to the ideas of that time, this motion turned eternally in a circle and therefore never moved from the spot; it produced the same results over and over again.

Engels' concept of nature was always as a whole and as a process. He escaped the specialisation which even in those days made it impossible for a physicist to understand biology or vice versa, and he laid down a general outline of this process which can still be the basis for an appreciation of the results of scientific research. The whole concept is expressed in its clearest form in the *Anti-Dühring* or gathered together in *Socialism, Utopian and Scientific*.

The Transformation of Quantity into Quality

The *Anti-Dühring* contains the clearest statement of the application and illustration of dialectical materialism in connection with natural processes. With particular care Engels deals with two of the main principles of dialectical method, the so-called change of quality into quantity, and the negation of the negation. Philosophers still cavil at the use of the phrase "transformation of quantity into quality" on the grounds that it is not quantity that changes into quality, because the quantity remains in the end. But the phrase is simply a shorthand way of referring to Hegel's law that purely quantitative changes turn into qualitative changes. It was in this form that Marx understood it, as shown explicitly in his letter to Engels (Letter 97). The examples which Engels gives, the case of ice turning into water, or water into steam, and that of the change of physical quality of a chemical substance with the number of atoms that are comprised in it, should have shown sufficiently clearly what this concept meant. The problem of qualities had always raised the greatest difficulties to the philosophers and furnished, as it still furnishes, a reason for invoking outside forces. From any logical materialist standpoint it is necessary to recognise that a new quality of a system is something not in any sense added to the system, but produced simply by a continuous change in its already existing components. To make his meaning perfectly clear, Engels cites as his final authority Napoleon (*Anti-Dühring*, p. 146):

> In conclusion we shall call one more witness for the transformation of quantity into quality, namely—Napoleon. He makes the following reference to the fights between the French cavalry, who were bad riders but disciplined, and the Mamelukes, who were undoubtedly the best horsemen of their time for single combat, but lacked discipline: "Two Mamelukes were undoubtedly more than a match for three Frenchmen; 300 Frenchmen could generally beat 300 Mamelukes, and 1,000 Frenchmen invariably defeated 1,500 Mamelukes."

Understood in this way, the concept of the transformation of quantity into quality can be, and is being, extremely valuable in scientific thought. We are learning more and more that specific qualitative properties of bodies depend on the *number* of certain of their internal components. If an atom can only

link with *one* other atom, the result is a gas. If it can link with *two* or *three*, the result will be a solid of fibrous or platy character. If with *four*, a hard crystalline solid like diamond. If with *more than four*, a metal. Similarly the processes of freezing, boiling, vitrification, etc., depend on what are now known as "co-operative" phenomena. It takes a million or more molecules to make a substance which can be recognised as a solid or liquid: a smaller number leads to the qualitatively different colloid state.

The Negation of the Negation

It is the same with the principle of the negation of the negation, which Engels illustrates with the famous examples of the barley seed negating itself into a plant and the plant further negating itself into many seeds, as well as the mathematical examples of the product of negative quantities and the differential calculus. These are the kind of statements that until recently made dialectical materialism seem quite unacceptable, indeed incomprehensible to scientists trained along official lines. Negation has always seemed to them something only applicable to human statements, but this is just a defect of language. If we had a better word to describe the transformation of something in the course of its own inner development into something different from itself, and later, its retransformation into something more like itself again, that word would take the place of negation. And if Hegel's and Engels' works had been treated on their merits instead of as something to be attacked in every possible way, the sense of their use of "negation of negation" would have been clearly apparent. But this, of course, would also have meant the recognition of the necessity of revolution, and that was far too uncomfortable to be accepted.

Just as the transformation of quantity to quality, so the principle of the negation of negation finds many examples in modern science. In almost every physical process in nature there is a tendency for the process itself to create an opposition which ultimately brings it to a stop, which in turn results in the disappearance of the antagonistic process and the reestablishment of the original one. Take, for example, the case of the building up of mountain ranges due to strain in the earth's crust. This results in increased weathering which

destroys the mountain range and accumulates sediments which lead to further crust strains, leading to further mountain building, etc. From modern physics, which is full of dialectical contradictions of this type, to Freudian psychology, where instincts and their repressions act in dialectical opposition, the whole of modern science is unconsciously affording more and more examples of the value of this aspect of phenomena.

The Dialectical Process of Nature as a Whole

But Engels did not confine himself to scientific illustrations of the validity of his philosophical position. His main task was a constructive one, and he gives in several places in his Letters, in the *Anti-Dühring*, and in the essay on Feuerbach, his general view of the dialectical process of nature taken as a whole. (See particularly Letter 232 and Chapters 5 to 8 of *Anti-Dühring*.) In the omitted fragment from Feuerbach (p. 76 of the English edition) he recapitulates the chief points in which the science of his time had served to lay the basis of a comprehensible materialistic view of the development of the universe. In this he lays stress on three discoveries of decisive importance:

> The first was the proof of the transformation of energy obtained from the discovery of the mechanical equivalent of heat (by Robert Mayer, Joule and Colding). All the innumerable operative causes in nature, which until then had led a mysterious inexplicable existence as so-called "forces"—mechanical force, heat, radiation (light and radiant heat), electricity, magnetism, the force of chemical combination and dissociation—are now proved to be special forms, modes of existence of one and the same energy, i.e. motion. . . . The unity of all motion in nature is no longer a philosophical assertion but a fact of natural science.
>
> The second—chronologically earlier—discovery was that of the organic cell by Schwann and Schleiden—of the cell as the unit, out of the multiplication and differentiation of which all organisms, except the very lowest, arise and develop. With this discovery, the investigation of the organic, living products of nature—comparative anatomy and physiology, as well as embryology—was for the first time put upon a firm foundation. The mystery was removed from the origin, growth and structure of organisms. The hitherto incomprehensible miracle resolved itself into a process taking place according to a law essentially identical for all multi-cellular organisms.
>
> But an essential gap still remained. If all multi-cellular organisms—plants as well as animals, including man—grow from a single cell according to the law of cell-division, whence, then,

comes the infinite variety of these organisms? This question was answered by the third great discovery, the theory of evolution, which was first presented in connected form and substantiated by Darwin. . . .

With these three great discoveries, the main processes of nature are explained and traced back to natural causes. Only one thing remains to be done here: to explain the origin of life from inorganic nature. At the present stage of science, that means nothing else than the preparation of albuminous bodies from inorganic materials. Chemistry is approaching ever closer to this task. It is still a long way from it. But when we reflect that it was only in 1828 that the first organic body, urea, was prepared by Wöhler from inorganic materials and that innumerable so-called compounds are now artificially prepared without any organic substances, we shall not be inclined to bid chemistry halt before the production of albumen. Up to now, chemistry has been able to prepare any organic substance, the composition of which is accurately known. As soon as the composition of albuminous bodies shall have become known, it will be possible to proceed to the production of live albumen. But that chemistry should achieve overnight what nature herself even under very favourable circumstances could succeed in doing on a few planets after millions of years—would be to demand a miracle.

The materialist conception of nature, therefore, stands today on very different and firmer foundations than in the last century.

The quotation shows amply that not only had Engels a complete grasp of the essential stages of development up to the human level, but that he also saw very clearly the gaps in the explanation—the primary gap at the beginning where, particularly in *Anti-Dühring*, he decisively combats the creationist ideas still so common in physical circles, and the almost equally important gap at the origin of life. But at the same time he indicates the means by which these gaps can be filled, and the progress of the last sixty years has shown hereto an enormous advance. These gaps are not bridged yet, but they are visibly narrowing. The next gap which Engels recognised was that of the development of human society from the animal stage, but it was not sufficient on this point to see and appreciate at their true value the results of scientific workers: here Engels was a scientist on his own account. The prevalent popular view in the nineteenth century was still that of the special creation of man. The materialists, led by Darwin, Huxley and Haeckel, maintained that man was only a superior ape distinguished by a larger brain. This brain which gave man his peculiar character was just such a product of evolution as a bat's wings

or an elephant's trunk. Engels and Marx saw that this crude explanation was hardly better than the theological one. They saw, long before anthropologists had taken up the question, that there was something qualitatively different about man which distinguished him from other animals, and that this was not an immortal soul, but the fact that man does not exist apart from society, and is in fact a product of the society which he has himself produced. Men, by entering into productive relations with each other, by the first exchange of food, and by the transmission of social characters through the family, became qualitatively different from other animals. These subjects were dealt with by Engels in an essay on "Work as the factor making for the transformation of Apes into Men," and in his most brilliant scientific work, *The Origin of the Family*. It is here that the full value of Engels as a scientist can be appreciated. Long before its recognition by the official anthropologists, he appreciated the significance of the matrilinear family group or clan that travellers and missionaries were showing to exist among all primitive peoples. With his wide historical learning he linked these facts with the history of early Greece and Rome, and showed first of all what an admirable economic unit the matrilinear family was at a certain primitive stage of production, and secondly how it broke down first to the patriarchal family, and finally to the modern small family, under the influence of the development of property, itself due to better methods of production. All the more recent work of anthropologists and historians has only served to confirm Engels' original ideas. The transformation from the matrilinear family to the present form has been traced also in China and can be seen in actual course of operation in all primitive societies on contact with European civilisation, as Malinowski in particular has shown in great detail. Engels' anthropological studies were not merely academic exercises: they were closely related to the great task that he shared with Marx, the transformation of capitalist into socialist society. In recognising the relatively happy, courteous and upright life of savages compared with their civilised descendants, he conceives the task of socialism as that of the return, again through the negation of the negation, to the nobility of the savage, without the sacrifice of the material powers which capitalist development had presented to mankind. His historical studies, particularly

The Mark, all led to the effecting of this transformation. He realised its difficulty (Letter 227):

> History is about the most cruel of all goddesses, and she leads her triumphal car over heaps of corpses, not only in war, but also in "peaceful" economic development. And we men and women are unfortunately so stupid that we never can pluck up courage to a real progress unless urged to it by sufferings that seem almost out of proportion.

Engels' Work and the Development of Science

What is the relation of Engels' work to the enormous development of science that has gone on since his time? What has already been said should be sufficient to show that this has only confirmed the value of his methods of approach and suggested their further application. For part of the intervening period this has been done by Lenin in *Materialism and Empirio-Criticism*, or by the writings of Plekhanov and Bukharin. At the moment this work is being carried forward both theoretically and practically by the younger Soviet scientists. There is no doubt that Engels would have recognised and welcomed the main advances which have occurred since his time. He would have recognised that four significant steps have been taken. The relativity theory has finally dethroned the mechanical materialism of the Newtonian school, but only in its mechanical and not its materialist aspects. Engels, who welcomed the principle of the conversion of one form of energy into another, would equally have welcomed the principle of the transformation of matter into energy. Motion as the mode of existence of matter would here acquire its final proof. The second great advance, the whole modern atomic and quantum theory, would also appear to him as a vindication of dialectical materialism. The diverse qualities of the natural elements now find their explanation simply in the number of electrons which compose them. Even more clearly than in organic chemistry, the transformation of quantity into quality is exemplified. The great advances in biochemistry which show the phenomena of living animals and plants as a function of the properties of the chemical molecules which make them up is a direct exemplification of what Engels had written about the chemical basis of life. Finally, the discovery of the mechanism of inheritance through the chromosome theory (originally

put forward by Mendel and now actually verifiable by microscopical observation) provides the material mode of transformation by which living animals develop and reproduce. These advances leave the main gaps in our knowledge still open, but we see more clearly than Engels could how they are likely to be filled. Nevertheless, Engels' work remains not only notable in its own time, but as valuable to us now in trying to keep the same all-embracing and historical approach to science that he possessed, and to use the methods he elaborated in pushing forward the solution of further problems. In doing this the scientist of today will make the memorial to Engels which is most in keeping with his spirit. For Engels was more than a scientist and a philosopher; he was a revolutionary. With him science acquired a new and positive meaning. As the last thesis on Feuerbach has it:

"The philosophers have only interpreted the world in various ways. The point, however, is to change it."

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ENGELS' *DIALECTICS OF NATURE*

IT is a sad reflection on the weakness of socialist thought in western Europe that Engels' great unfinished classic had to wait forty-five years in manuscript before it was published in German and might have had to wait for ever if it had not been for the initiative of the Soviet Union. But it is still sadder to think that we have had to wait a further thirteen years before we have been able to read it in English. This reluctance to bring out Engels' theoretical work is not, however, surprising. The tendency in German social democracy and even more so in the English labour movement has been to despise dialectical theory, ostensibly on the ground that it was old-fashioned and not in keeping with modern science, but really because, however much they might deny the connection between theory and practice, the social democrats felt instinctively that any basic theory other than the approved bourgeois science of the day would lead them to unpleasant revolutionary conclusions.

At last, however, we have the *Dialectics of Nature* in the excel-

lent translation by Clemens Dutt and illuminating notes and introduction by Haldane, and we can see how much we have missed and how much is still to be learnt from the great collaborator of Marx. The *Dialectics of Nature* was planned as a completion and summary of Engels' theoretical work. It was to include and go far beyond the more popular *Anti-Dühring* on the scientific side, though it was not aimed at the full political development that occurs there. Engels himself has provided in one of his notes what must have been the original table of contents, which contained five main sections: two of them historical, one on the history of science and the other of dialectics, a third and fourth on the main laws of dialectics and on their relation to science, and the fifth section, which was clearly intended to be the largest, covering the whole range of separate sciences from mathematics to sociology and economics. The book as we have it contains much of the first two parts, a sketch of the third and fourth, and largely fragmentary notes for the rest. But for all that it is the most valuable and suggestive treatment of the Marxist approach to science that has ever been written, with the possible exception of Lenin's *Empirio-criticism*. Except for certain complete sections such as the historical introduction and the remarkable essay on the transformation of ape to man (both of which deserve to be published separately) the book is not one to be read straight through, but rather one to study carefully and to develop the dozens of brilliant and thought-provoking ideas. It is true that many of the issues discussed in it are now no longer alive, they have been swept aside by the advance of science. But that advance, as Haldane points out in the introduction, has so often been in the direction that Engels foresaw and has only gone on to raise further issues to which Engels' method is just as applicable. And indeed the struggle against purely mechanical or idealistic ways of thought will go on as long as the struggle between capitalist and socialist methods of production with which they are associated.

Engels' purpose was primarily to show that the transformation of the dialectic from idealist to materialist is as applicable in the field of science as it is in social fields where Marx himself mainly used it.

It is, therefore, from the history of nature and human society that the laws of dialectics are abstracted. For they are nothing

but the most general laws of these two aspects of historical development, as well as of thought itself. And indeed they can be reduced in the main to three:

The law of the transformation of quantity into quality and vice versa;

The law of the interpenetration of opposites;

The law of the negation of the negation.

All three are developed by Hegel in his idealist fashion as mere laws of *thought*: the first, in the first part of his Logic, in the Doctrine of Being; the second fills the whole of the second and by far the most important part of his Logic, the Doctrine of Essence; finally the third figures as the fundamental law for the construction of the whole system. The mistake lies in the fact that these laws are foisted on nature and history as laws of thought, and not deduced from them. This is the source of the whole forced and often outrageous treatment; the universe, willy-nilly, is made out to be arranged in accordance with a system of thought which itself is only the product of a definite stage of evolution of human thought. If we turn the thing round, then everything becomes simple, and the dialectical laws that look so extremely mysterious in idealist philosophy at once become simple and clear as noonday.

Moreover, any one who is even only slightly acquainted with his Hegel will be aware that in hundreds of passages Hegel is capable of giving the most striking individual illustrations from nature and history of the dialectical laws.

We are not concerned here with writing a handbook of dialectics, but only with showing that the dialectical laws are really laws of development of nature, and therefore are valid also for theoretical natural science. (pp. 26–7)

Engels wished to show that the dialectic can furnish a philosophical basis for scientific thought in contradistinction to the prevailing empiricism of the time. He was under no illusion as to the neutral character of this empiricism:

Natural scientists believe that they free themselves from philosophy by ignoring it or abusing it. They cannot, however, make any headway without thought, and for thought they need thought determinations. But they take these categories unreflectingly from the common consciousness of so-called educated persons, which is dominated by the relics of long obsolete philosophies, or from the little bit of philosophy compulsorily listened to at the university (which is not only fragmentary, but also a medley of views of people belonging to the most varied and usually the worst schools), or from uncritical, and unsystematic reading of philosophical writings of all kinds. Hence they are no less in bondage to philosophy, but unfortunately in most cases to the worst philosophy, and those who abuse philosophy most are

slaves to precisely the worst vulgarised relics of the worst philosophers.

It is sufficiently clear from the finished parts of the work how well he would have succeeded in doing this. In each of the subjects he treated, whether it is in mechanics or biology, he went straight to the core of the problem and escaped just those preconceived ideas which we now see from the subsequent history of science were what held back the advance at the time.

The first section contains one of the finest and clearest pieces of writing that Engels ever did, a Marxist history of science in twenty-four pages. We in England have been coming to this view of science only in the last ten years, and this only as a result of Marxist ideas transmitted through the Soviet Union. Engels' treatment is still very much in advance of many popular accounts of the history of science that claim to be Marxist. The next completed sections deal with the actual dialectic of the sciences, but only of the physical sciences—mechanics, heat and electricity. In mechanics Engels is chiefly concerned with emphasising the importance of the transformation of quantity into quality and of the relations of matter and motion. He saw more clearly than most distinguished physicists of his time the importance of energy and its inseparability from matter. No change in matter, he declared, could occur without a change in energy, and vice versa. In many ways his questioning of fundamentals was of the kind that many years later led to the formulation of the quantum theory and the relativity theory—but if Engels' work had been more known to the scientific world both these theories would probably have been discovered sooner and would be free from many of the idealistic difficulties from which they still suffer.

His general physical standpoint was based on the dialectical relation of attraction and repulsion; though it is clear from the way he uses these terms that they are not to be understood as merely mechanical forces drawing bodies together or pushing them apart, but essentially as motions, the one tending to bring everything in the universe together and the other to keep everything apart, the first therefore associated with potential and the second with kinetic energy. This substitution of motion for force which Engels battles for throughout was the starting-point of Einstein's own criticism of mechanics.

Even more interesting from the point of view of modern

science is Engels' treatment of chance and necessity. From quantum mechanics to genetics, the modern scientist is tending more and more to treat all laws as statistical results of chance. This view is already fully developed by Engels:

> Common sense, and with it the great majority of natural scientists, treats necessity and chance as determinations that exclude one another once for all. A thing, a circumstance, a process, is either accidental or necessary, but not both. Hence both exist side by side in nature; nature contains all sorts of objects and processes, of which some are accidental, the others necessary, and it is only a matter of not confusing the two sorts with one another. (p. 230)

Engels shows that this distinction not only cannot be maintained but is not even maintained in practice by the scientists. He quotes the example of Darwinism to show how the necessity of evolution followed from the chance of natural selection:

> Chance overthrows necessity, as conceived hitherto. The previous idea of necessity breaks down. To retain it means dictatorially to impose on nature as a law a human arbitrary determination that is in contradiction to itself and to reality, it means to deny thereby all inner necessity in living nature, it means generally to proclaim the chaotic kingdom of chance to be the sole law of living nature. (p. 234)

Chance and necessity are dialectically connected and cannot be considered apart from one another and apart from the whole scheme of the universe; what is chance on one level, say the motion of molecules, is necessity on another, the laws of pressure and gases.

It is a pity that Engels was never able to write the biological section as he had planned, and that here we have only disconnected notes. But there is enough to show that here again he was far ahead of his time, and is still of the utmost value as a guide to clear thinking. To Engels there was a necessary connection between the structure of an organism as a whole or in detail and its functions, and that connection could only be understood in relation to its evolutionary history. Much of the discussion is concerned with the question of the origin of life. Here Engels joined issue with two of the greatest scientists of his age, Pasteur and Liebig. All that Pasteur had shown, he claimed, was that it was not possible to produce life afresh in sealed vessels, not that life had never arisen from lifeless matter

or that it might be made from it. As to Liebig's suggestion that it might have come from somewhere else or had existed eternally, he is able to show on purely chemical considerations how question-begging and absurd this is. Every chemical compound, according to Engels, comes into existence only at a certain time in the development of the universe when the conditions are appropriate for it; and when it does come into existence it manifests this by entering into its characteristic relations. Neither carbon compounds or proteins are ideal forms, but are themselves witnesses of the conditions on a cooling sun or a cooling planet. It is here that occurs his celebrated remark that life is the mode of existence of proteins.

The short essay on the part played by labour in the transition from ape to man fittingly closes the scientific section. Together with *The Origin of the Family* it gives us a Marxist approach to social anthropology. This approach has been long delayed but is being used more and more by anthropologists. This is probably the most important part of the whole book because in it we find most definitely stated the view that man owes his uniqueness to the existence of society and that society in the first place is common labour:

> The mastery over nature, which begins with the development of the hand, with labour, widened man's horizon at every new advance. He was continually discovering new, hitherto unknown, properties of natural objects. On the other hand, the development of labour necessarily helped to bring the members of society closer together by multiplying cases of mutual support, joint activity, and by making clear the advantage of this joint activity to each individual. In short, men in the making arrived at the point where *they had something to say* to one another. . . . First comes labour, after it and then side by side with it, articulate speech—these were the two most essential stimuli under the influence of which the brain of the ape gradually changed into that of man, which for all its similarity to the former is far larger and more perfect. . . . The reaction on labour and speech of the development of the brain and its attendant senses, of the increasing clarity of consciousness, power of abstraction and of judgment, gave an ever-renewed impulse to the further development of both labour and speech. This further development did not reach its conclusion when man finally became distinct from the monkey, but, on the whole, continued to make powerful progress, varying in degree and direction among different peoples and at different times, and here and there even interrupted by a local or temporary regression. This further development has been

strongly urged forward, on the one hand, and has been guided along more definite directions on the other hand, owing to a new element which came into play with the appearance of fully fledged man, viz. *society*. Hundreds of thousands of years—of no greater significance in the history of the earth than one second in the life of man—certainly elapsed before human society arose out of a band of tree-climbing monkeys. Yet it did finally appear. And what do we find once more as the characteristic difference between the band of monkeys and human society? *Labour*.

(pp. 282–5)

The characteristic of labour socially carried out is that it raises man from the animal that merely uses nature to one that masters it, but Engels sees very clearly the limitations of this mastery. He traces the effects of undesired physical consequences of human interference with nature such as cutting down forests and the spreading of deserts. He goes on to notice the far more disastrous and undesired social effects of this mastery in the building up of classes and states leading us to the situation which we face in the world today. Just at this point the manuscript breaks off abruptly, but the message is clear enough. It is a message which the whole of the life of Marx and Engels taught, that humanity only reaches its full stature when it consciously organises to master both material and social environment, and that to do this man must first sweep aside the relics of the old world by his revolutionary action.

1940

DIALECTICAL MATERIALISM

DIALECTICAL MATERIALISM is the most powerful factor in the thought and action of the present day. Even its most bitter enemies are forced to recognise its analysis and ape its methods. It is all the more essential that it should be correctly understood by all those who want to play a conscious part in the world and not be carried away by events they can neither understand nor control.

This paper is a contribution towards that understanding, but it can only be an outline of the leading ideas, necessarily incomplete, because dialectical materialism is not merely a

philosophy, but a programme of action. The historical and economic aspects are dealt with in other articles. Here I am chiefly concerned in showing how Dialectical Method can be derived from that co-operative struggle with the material world which we call science, and what it can do and has done to aid the development of science and its application to human welfare. At the same time, I am attempting to combat some of the many misunderstandings and misrepresentations of dialectical materialism rife at the present day; in particular the one that attempts to separate dialectical materialism, as a pure philosophy, from revolutionary politics.

Transformation

The central idea in dialectical materialism is that of transformation. The two-sided problem is: How do transformations occur and how can we make transformations occur? The approach to this problem lies not in a philosophical analysis and definition of transformation, but in an examination of all observable facts in the universe as they are known to us from various sources, scientific or historical, but more particularly in those political and economic transformations in which conscious action takes part. Dialectical materialism includes a description of the universe and its development, but to it description is only a basis for interpretation and action, not an end in itself. It uses the results and methods of science, but only as the material for the solutions of its more general problems.

Materialism

The starting-point is the material universe as we know it. It is useless to quibble here over the meaning of words. It does not make a universe more or less material whether it is made of rocks and wood and flesh, or of molecules and atoms, or of neutrons, electrons or protons. The idealist standpoint in which the universe appears as compounded of the sensations or intuitive ideas of the individual is a glaring example of the general, here deliberate, ignorance of philosophers. The ideas, the sensations even, of the philosopher can be no fundamental starting-point; they are plainly conditioned by personal

history, social and class tradition, biological evolution and physical law.

The priority of a material universe is taken as given, given by the experience of each individual and by the cumulative experience of mankind, an experience expressed not so much in meditation or conscious verbal formulation as in action and practice. The basis is laid in what people do, not in what people think. The material universe is taken as prior, not only in a temporal sense, as saying "There was a universe before there was anyone to think about it," but also in a substantial sense, as without a material basis no one would be thinking here or now.

This fundamental materialism does not, as the materialism of many scientists, stop short of the human stage; it implies that material considerations and material forces must be taken into account in the understanding of human development and activity; it asserts that before we can understand the history not only of politics, but also of science, religion and philosophy, we must know the material, technological basis without which none of these developments would have been possible or even conceivable. No dialectical materialist claims to account for all these things on the basis of that knowledge only; it is precisely there that the nature of dialectic comes in. But by insisting on this basis dialectical materialism cuts away at one blow the whole set of idealistic, mythological and mystical views of the universe that are expressed in all religions and all other philosophies.

Idealism

Here arises the first difficulty; well-meaning people with ideals of human betterment object to accepting as fundamental this materialist doctrine. They point to the nature of their personal experience, which seems impossible to render in material terms. They prefer to interpret the universe by postulates of God, of ideas, of emergence, of vitalism, or to remain in the complete security of an agnostic scepticism. Now, these postulates are mere translations into transcendental terms of difficulties which they in no way help to solve, for the invocation of God or any of his more concealed equivalents—just because it can be done when faced with any intellectual or moral difficulty whatever—removes any necessity for a rational

treatment of the world. The appeal is not only gratuitous; it appears plainly false once the essential ignorance of its originators and their modern followers is laid bare by historical analysis.

Up to a certain degree of natural or invincible ignorance—a stage passed by the more intelligent of men somewhere about the fourth millennium B.C.—a strictly anthropomorphic view of the universe was not only permissible, but obligatory. Since that time it is merely a survival, and every increase in the positive control over mechanical, economic and biological forces makes it appear more and more a barbaric anachronism. Ideas, Wills, Providences, if they are not those of living, working men, have no more rational justification for existing in the modern universe than have the spirits of ancestors or totemic animals. Yet it was ignorance still on the part of the eighteenth-century rationalists that made them believe that merely to point this out would be to destroy such a fashion of thinking. There were then, and still more there are today, very substantial and compelling reasons for accepting, or at any rate professing, a transcendental or metaphysical view of the universe. As long as the ways of God are hidden from men, as long as we are to wait for the emergence of a new social order or for the inner development of thought and will, or as long as this visible world is merely illusory or incalculable, then there is no call on individuals to leave their private occupations and join in the first real conscious attempt at making human history.

Idealistic, religious and metaphysical views of the universe lead, as far as social action is concerned, at the best merely to quietism and palliative good works; at the worst to the support of every form of interested reaction. It is possible to trace in detail how every form of non-materialist philosophy finds itself ultimately allied with political reaction and wealth. Lenin's *Materialism and Empirio-criticism* stands as an exposure of those connections thirty years ago, an exposure which points to the permanent impossibility of separating compromise in ideology from compromise in politics.

Dialectical not Mechanical Materialism

Dialectical materialism only begins with the refutation of fantastic and reactionary philosophy; that task had been

accomplished years ago by the simple mechanist materialism of the eighteenth century, or even in the dim past of Democritus and Lucretius. But the world view of the mechanical materialist is distorted as a result of a different but equally dangerous ignorance: the simple materialist invokes God, but in a way so indirect that he is unconscious of the fact. His idea is one of a universe of which a complete quantitative account at all times is given by knowing at one time the position and velocity of all the points in it—the universe of Newton, Laplace or Einstein. It implies not only a detailed and exact sequence of mechanical causation, but also a knowledge and power of calculation beyond individual or co-operative human effort. Only God knows, and only God can tell how such a universe can be or move. Some former materialists have seen through this and, not very surprisingly, have come down on God's side, notably Jeans in *The Mysterious Universe.*

But mechanical materialism suffers from another defect; while it is ostensibly based on science, it is really based on a mythological abstraction from science, a reduction of all the universe to a number of separate abstract categories: space, time, matter, motion. Now, the whole body of the scientific knowledge of the universe does not rest at all on the possibility or actuality of a reduction to these categories. There are still only very small parts of the scientific fields which can be treated in this way, and the attempt to understand it upwards from pure mathematical physics to sociology is faced with a series of impassable breaks which are merely slurred over with a pious hope that ultimately we shall be able to "calculate." In fact, scientific practice proceeds quite differently by attacking the universe at all points, and scientific knowledge uses in any field a set of entities differing in quality, in their laws of combination, from those used in other fields.

Now, the essential task of any comprehensive understanding of the universe is not to build up an abstract system of connections and deductions into which experience will fit, but to use experience in its already most highly organised state of scientific knowledge, where it exists, to suggest its own form of interconnection and development. The game must come before the rules and not the rules before the game.

The Dialectic Method and Scientific Method

Now, this is precisely what dialectical materialism does. It is true that it borrows the former part of its title from the most consistent idealistic philosophy that has ever existed, but the inversion of content that Marx gave the Hegelian dialectic was much more than a mere *jeu d'esprit*; it was the foundation of a new way of understanding and changing the universe. True, Marx studied Hegel, but the dialectic of Marx, which neither Hegel nor the Hegelians would accept for a moment, is derived far more from his wide knowledge of the universe, and comes more directly from the concrete experience of the economic and political struggles of the nineteenth century than from the philosophy of his youth. As he himself says:

> Of course the method of presentation must differ formally from the method of investigation. The aim of investigation is to appropriate the matter in detail, to analyse its various developmental forms, and to trace the inner connections between these forms. Not until this preliminary work has been effected can the movement as it really is be suitably described. If the description prove successful, if the life of the subject-matter be reflected on the ideal plane, then it may appear as if we had before us nothing more than *a priori* construction.
>
> My own dialectical method is not only fundamentally different from the Hegelian dialectical method, but is its direct opposite. For Hegel, the thought process (which he actually transforms into an independent subject, giving to it the name of 'idea') is the demiurge (creator) of the real; and for him the real is only the outward manifestation of the idea. In my view, on the other hand, the ideal is nothing other than the material when it has been transposed and translated inside the human head.[1]

The success of Marx was possible only because he was not, in contrast to the founders of most philosophic systems, an ignorant man. Ignorance of relevant knowledge, a partial and departmental view of the universe, i.e. Bacon's "Idol of the Den," has been the ruin of many ambitious philosophic and scientific systems. Marx himself realised this and overcame it. He added to the knowledge of materialist science that of politics and economics, and united them in that fundamental idea of development arising from the struggle of opposites. Except in the field of economics and politics, which become virtually new

[1] Preface to second German edition of *Das Kapital*. From the translation by E. and C. Paul, Everyman's Series, ii, 873.

sciences in his hands, Marx did not aim at transforming science or creating a new or a more general science.

Dialectical materialism is not a part of separate scientific disciplines or even of general scientific method. It is concerned primarily with the origin of the new, and hence contains an ingredient as essential to science as scientific method itself. This ingredient, however, has remained obscure to the scientists simply because it was so universally present in all their work. Scientific method has as its object the construction of general laws and theories from observation and experiment; it proceeds by a rigid logic to exclude any possible alternatives to its formal description. Every scientific paper aims at leaving the reader in no doubt that its conclusions follow inescapably from the observations which are its premisses. But no scientist would like to claim that the argument used in his publications was the actual chain of ideas that led him from his observations to his conclusions. Then why were those observations and experiments made in the first place, and why was the very problem which the scientist set himself to solve ever propounded? These inquiries are no part of the scientific method; if they are thought of at all it is in the past as scientific history, whereas actually they refer to the living, directing influence in all scientific research. What is it that points from old knowledge to new discovery? Up till now the actual development of science has been left to simple nature, has been left on the near view to the psychology of the individual scientist, or, on the more extended view, which Marx was the first to point out, to the social and economic conditions of the times in which the individual scientist worked.

Dialectical materialism is concerned precisely with this *indicative* aspect of all human activity, not only of scientific activity. It is not a critique of science; it does not claim to be a substitute either for experimental method or for the logical proof of laws of theories, but it does in a very important way supplement science by providing a definite method of coordinating the larger groups of special sciences and in pointing the way to new experiment and discovery.

Dialectic Process in the Material World

Marx drew his picture of the materialist dialectic from the actual observations of contradictions in the development of

capitalism in his time. The primary contradiction was that of the social co-operative form of production with the individual form of appropriation, leading inevitably to the growth of the exploited proletariat and to the second contradiction of capitalist competition, with its recurrent and ever-deepening crises of production. This, Marx saw, could only be solved by revolution and the dictatorship of the proletariat. These contradictions showed him that the opposition of ideas in Hegel's philosophy was paralleled by an opposition of actual forces in the real world. More than that, the very dialectic of Hegel with its tiradic form of thesis, antithesis and synthesis now appears as a reflection in the world of thought of the types of opposition that occurred in the material world, completely independent of thought. It was Engels who first attempted to generalise this materialistic inversion of the Hegelian dialectic by showing how these unions of opposites were not confined to human society, or even to living things, but occurred at all stages of the organisation in matter. These oppositions are possessed of critical importance, in that they were the forerunners to the spontaneous processes of real change which go on in the universe. Here dialectics was pointing towards the solution of a central philosophical problem, the problem of the origin of the new.

The existence of dialectic opposition in the material world has always been a great stumbling-block to non-Marxists. It is not, of course, that such dialectical oppositions have been perceived only by Marxists, but that, when perceived by non-Marxists, they have always been considered to be serious blemishes on our knowledge of the world—things to be endured possibly for lack of knowledge, but ultimately to be cleared away, leaving a straightforward account of the universe permanently free from all dualities and contradictions. Yet the course of science from Marx's day until today has shown Marx to be far more right than the scientists. Until the Revolution, Marxism has had practically no effect on the course of the physical sciences, yet the history of the physical sciences in the nineteenth and twentieth centuries shows a steady drift away from the simple mechanical views of Newton into a set of irreducible dialectical opposites, such as wave and particle, matter and energy, statistical and determinate, aggregating and segregating processes. The attempt to comprehend them

has been too much for the philosophy of many scientists; in despair at these contradictions, even the mysteries of religion begin to seem preferable. But from the dialectical point of view there is nothing illogical in any of these pairs of united opposites. The fault is rather with a logic which by denying them is at variance with actuality, and which tends to make us withdraw from recognition or participation in the real world.

Matter and Motion

The mere static existence of opposites is, however, only the beginning of dialectics; actually opposites do not exist statically. None of the qualities mentioned is conceivable except in the process of movement and transformation. The relations, for instance, of mass and energy are seen only in the violent transformations of rapidly moving particles into light, and here again we come to one of the most important positive contributions of dialectical materialism—the equivalence and inseparability of matter and motion. From the crude experience of man, an experience rationalised but unchanged by the works of Greek philosophers, matter was essentially an inert substance. Any motion which it had was due to the continual working of forces on it. This was a very genuine statement of the plain economic fact that in order to get anything moved, work—generally human work—had always to be put into it. The Renaissance saw differently; armed with the invention of gunpowder, Leonardo and Galileo, and finally Newton, showed that the continuous effort of the prime mover was unnecessary, that, given an initial impulse and in the absence of retarding friction, the motion of a body could never be lost. But they still thought of matter as essentially inert, and the prime mover, God, merely retired from the business of continually turning the handle of the universe to that of giving it an initial push. But the Newtonian view, as amply shown by recent physics, is itself an anthropomorphism only one degree less direct than the Aristotelian. From the dynamics of relativity motion and mass become equivalent. This conclusion, which required all the refinement of experimental technique of Michelson and the mathematical genius of Einstein to demonstrate in the twentieth century, was grasped in principle by Marx and Engels before the middle of the nineteenth century. We no

longer seek for an explanation in terms of a primary impulse given either at the beginning of universal history or at any subsequent point. The way is now open for finding the laws of self-movement and transformations of material systems, and this involves the dialectics of matter in its most complete form. The same union of opposites that removes the necessity for a prime mover in mechanical systems also removes the necessity for the invocation of an external agent in the more complicated systems of chemistry, of life, and of human society.

The Origin of the New

The essential task of materialist dialectic is the explanation of the appearance of the qualitatively new. The very statement of this problem marks an important stage in the history of human thought. To the primitive mind, once it had grasped the specific nature of things, there was nothing qualitatively new. True, the world renewed itself, but essentially without any departure from a fixed pattern. Day followed day, spring came after winter, a generation died and a new generation took its place. The secular regularity of the world was marred only by divine intervention; God made the world, God would in his due time destroy it. It was not until the fifteenth century while commerce opened one new world and technics and science another that this picture faded. The world was changing visibly; change therefore was possible and even necessary. The idea of progress gradually displaced that of a divinely appointed world order.

The next stage is shown by the attempt to describe the world in terms of this progress, to give an account of the origin of the phenomena in the world, an account appearing in its most profound and startling form in Darwin's *Origin of Species*. But Marx was at the same time working on a far wider generalisation. What he was seeking was essentially the origin of origins. How was it that the things in this world, which, looked at close, appear in such permanent and fixed form, actually are constantly changing, and changing not only in an imperceptible, quantitative way in growth or decay, but also suddenly and qualitatively, new things always appearing that had never been in the world before? To many, to most of Marx's generation, still caught in the net of anthropomorphism,

all this showed no more than a purpose in the universe. It was an idea they could well understand. The idea of purpose explained nothing, but its end was justified; and the end was themselves, with their trade, their machinery, their liberal thinking, and their grasp of the ideal of progress, to more trade, more machinery and more liberal thinking. Though it might seem of no importance at any moment to have an incorrect explanation of the past, it is, in fact, fatal so to misconstrue the past as to gain a false impression of the present and the future. We have only to look at the world today to see where the evolutionary trend and the purpose of the Victorian bourgeoisie have led us. Who seems right now, Marx or Herbert Spencer? Marx had passed beyond the stage of merely describing progress; he was searching for its inner mechanism, the knowledge of which is not merely an academic knowledge of the past, but a clue to practical activity in the present and the future; and that knowledge he found by considering how the changes from one state to another were due to the inner contradictions of the earlier stage.

It is possible to state this part of the dialectic in a more or less physical and mathematical way, though, as we shall see later, this is a very partial statement. Given any system (and it must be an active one, because, as we have already seen, static systems are mere abstractions) then, besides its main activity there will always be left certain residual effects some of which will be cumulative. Now, these residual effects can be divided into those that contribute to the main activity and those that oppose it. The former may be reckoned as simply part of the main activity; but the latter are bound in sufficient time and in the absence of external disturbances to accumulate to such an extent that the whole nature of the system and its activity are transformed. In the simplest possible case this is merely an explanation of the universally recurring oscillatory changes. Any process, once set going by an initial impulse, continues in the absence of external forces until, passing its equilibrium position as the result of its own momentum, it is brought to a stop and reversed. But in more complicated cases, instead of mere oscillatory back-and-forth movement as the type of cyclic change everywhere, we get as the result of the internal opposition and stopping of the primary activity a new and qualitatively different one.

Quantity into Quality

The change of quantity into quality is a second leading principle of dialectical materialism. The immediate apprehension of quality, its peculiar and indescribable nature, has always made it a favourite recourse of mystically inclined thinkers. The strict mechanist denies quality altogether, and so moves from the field of experience into that of abstraction. To the dialectical materialist, on the other hand, quality, new quality, always appears just at those moments of transition when a system undergoing purely quantitative change breaks down as the result of its self-engendered contradictions. Thus quantity changes into quality. The classical physical example is the change from ice into water. Here we have a rigid crystalline body on the one hand, a fluid, amorphous body on the other, typically qualitatively different. The process of change from ice to water is brought about simply by heat. The crude view is that it is heat which gives the qualities of fluidity and internal regularity to water. But if we add heat to ice we do not in fact observe with the gradual addition of heat any lack of rigidity and crystallinity until a specific point when both disappear suddenly together to be replaced by the fluidity of water.

This is the common, everyday observation, but scientific analysis only emphasises the picture. The molecules in ice stand, as Newton phrased it, in ordered rank and file; in water they are totally disordered. Yet there is no transition between them at which one can say they are more or less ordered—they are either altogether ordered or not at all ordered. The qualitative distinction is still there, although expressed in more physical terms, and that qualitative change is brought about by a simple quantitative change of the mean energy of the molecules. Below a certain mean energy they are ice, above a certain mean energy they are water.

Transformations of this type occur all through the inorganic and organic world. Practical people and scientists have never found any difficulty in accepting them. The whole of scientific development since Marx has been noted for the increasing number and importance of these transformations. To the nineteenth-century physicists the absorption and radiation of light were continuous processes; now they appear in

discontinuous quanta. To Darwin evolution was a matter of continuous, imperceptible variation; now it appears as a series of discontinuous genetic mutations. These ideas are readily acceptable by modern science; it is only when the idea of equally sudden changes in the social civilisation are contemplated that the "unscientific" nature of the Marxian analysis is cried out against.

Applications of Dialectics to Nature and Science

There are, of course, a number of examples of transformations from quantity to quality which take place without this definite jump, but they are of more verbal than scientific importance, as, for instance, when we have to decide how many hairs a man's head must lose before he becomes bald, how many grains of sand there must be in a pile before it becomes a sand-dune. Hot water is undoubtedly qualitatively different from cold water, although there is no sudden transformation between them. The nature of these differences can be understood only by grasping a principle implicit in dialectical theory, one in which practical Marxists find no difficulty, but which is a permanent stumbling-block to non-Marxist critics. That is the conception of the Marxian field of revelance. The unity of opposites and the change from quantity into quality are, from the Marxist point of view, universal modes of behaviour of matter, modes of the same generality as the conservation of energy. But that does not mean that if any small portion of the field of nature or humanity is considered in isolation it would be possible to demonstrate in it the dialectic processes. Such a portion might be only a part of a larger process, and changes in it only become understandable dialectically when the larger process is considered as a whole. From the most general standpoint the only field for operation of the dialectic is the universe as a whole. But to say that the whole universe is a unity is not equivalent to saying that everything is equally related to everything else; and it is just as true and significant that the processes in the universe have a natural division into a hierarchy of qualitatively different organisations as that the whole forms an organic unity.

The dialectic processes are exhibited most clearly when we are dealing with an organisation during a period of time long

enough to include a great number of its established cyclical changes. But it must not at the same time be violently affected by other organisations, whether higher or lower in the organisational hierarchy. In such a case these other organisations enter into the dialectical field of relevance, and the original one cannot be considered by itself. The classical example is here that of the transformation from seed to plant. Neither seed nor plant is a permanent organisation; the seed contains in itself physical, mechanical and organic structures that will regularly ultimately prevent it from continuing as a seed, but that is only if we consider the system plant-seed, in an environment which may be taken as the normal, statistical environment of seeds. If now this is interfered with, either by wind or rain or human act, the destruction of the seed by these changes is no part of the dialectical change of the seed itself. We are now dealing with a wider field of relevance, with the field weather plus seed, or man plus seed. That again has its own dialectic; the man grinding the seed of corn certainly negates it as a seed, just as when the seed naturally germinates; but that negation is part of the dialectic cycle of crop-food-cultivation-crop, not of the smaller cycle of seed-plant-seed.

An even greater stumbling-block to the non-Marxist has been the materialist reinterpretation of the Hegelian dialectic movement of negation expressed in the classical equation $-a \times -a = a^2$. The field of relevance here is no longer the Hegelian field of pure idea but the "mathematician and his operations." The actual example marks an important stage in the history of the development of mathematics, and consequently in the practical mastery of humanity over material forces. The operation of multiplying negative numbers is shown to lead to a positive number, but one mathematically of a different quality, technically of a higher order of magnitude. The example has been chosen rather than $a \times a = a^2$, or even $a \times -a = -a^2$, because in both of these the ideas are simpler; the operation of a negation either does not enter, or in only a trivial manner without any negation of negation. The whole history of mathematics is a beautiful example of dialectical progress, new operations arising constantly, never by slow outgrowth from older ones, but suddenly by overcoming the contradictions limiting their use. The sequence of contradictions exhibited by the development of the use of number—whether

integral or fractional, rational or irrational, real or complex, commutative or non-commutative—forms a set of dialectical opposites in which the syntheses successively lead to further contradictions.

Dialectical materialism is not a formula to be applied blindly either in the natural or human world. The facts must first be known and the field of application delimited before it is possible to say whether such and such a phenomenon exhibits a dialectic movement or is a part of a larger process exhibiting such a movement. It is the neglect of this factor of relevance that makes the greater number of scientists whose only acquaintance with the dialectic is by hearsay or casual reading fight shy of it. They do not see how it applies to the experiments that they are actually performing, or how it can help them in predicting results. To apply the dialectic to the material, whether inorganic or biological, in the hands of a scientist is simply to make nonsense of it. The dialectic must be applied to the scientist and his material at one time; the field of relevance here covers the scientist, his education and upbringing, the administration of his laboratory, and the general technical, social and economic conditions of the country he is working in, in less and less degree. The application of dialectics to experimental science is much more its application to the history of science and the directions of fruitful future scientific fields of discovery than it is to the actual descriptions and deductions from concrete experiments.

Marxist Analysis of the History of Science

In this field it has already proved itself very fruitful. Note the brilliant study of Newton by Hessen in *Science at the Cross-roads*. This is a model of the dialectic method. In the first place, the material, technical background of Newton's life and work is considered. It is shown how the general type of mechanical problem he set himself to solve was conditioned by the current needs of technics, particularly the technics of military and naval warfare. The laws of mechanics, the motions of the planets and the moon, the theory of the tides, had all to do with the ballistics and navigation at a period when the supremacy of England was being established for the first time and she was taking on the material as well as the intel-

lectual heritage of Dutch commercialism. But that is only half the story; it merely explains why Newton studied the subjects he did and how he found the material necessary for his investigations; it does not explain the form in which he put the theoretical conclusions from the results of his own and other observations. To find this form it is necessary to move one stage further away from material considerations to the religious and religio-political ideas of a time when these were being violently shaken and remodelled, as the result of the changing basis of property from land to commerce and industry. Newton's physics, as Hessen shows, is shot through and through with Newton's theology. It was Newton's idea of God that made him place matter and motion arbitrarily in absolute space, in a preformed receptacle. And this physics of Newton, derived from his theology, itself at one more remove affected the ideological form of subsequent science, until it was shaken in turn by the work of Einstein in another period of economic, political, and consequently of ideological change.

Without the Marxian analysis the history of science appears as the history of pure ideas, lit up by flashes of individual genius as meaningless and as unmanageable as any play of chance. Science had flourished at certain periods and died away again; it is flourishing now, tomorrow perhaps it will disappear. But the Marxian analysis, by explaining simultaneously both the flourishing and the decay, shows what must be done in order to preserve and extend the scope of science. It shows that modern science has itself, by its own development, destroyed the possibility of the old methods of scientific discovery by individual, inspired, haphazard work. Science now depends on large-scale, international organisations of laboratories, these almost on the scale of factories, and it implies with that a corresponding economic and political organisation to support these laboratories, to utilise their results, and to suggest the type of problems for them to attack; for science does not necessarily or even usually produce most of its own problems. These conditions are not to be found in a rapidly disintegrating capitalistic society harassed by economies and preoccupied by preparations for war. The future of science lies in the communist state.

Continuity and Discontinuity

From these examples of the application of dialectical materialism in mathematics and science we can return to the question of the different types of change, whether slow and continuous or abrupt. Continuous change always appears in a dialectical account as part of a wider movement which includes discontinuity. Narrow research, focused on a region of study small in time and space, will see mainly continuous changes, and may incorrectly claim that no other change can take place. Dialectical materialism, in correcting this, avoids the opposite mistake, and considers continuous change as an important, even essential, forerunner of discontinuous change. The relativist will object here that every change is continuous or discontinuous according to our scale of time. This is a true but quite an irrelevant objection. In considering the transformation of a system we must take a time-scale appropriate to it. An explosion, in the time-scale of an atomic vibrator, is an extremely slow process; but from the relevant time-scale of the total duration of the explosive it is instantaneous. The formation of a mountain range, which may take hundreds of thousands of years, is equally instantaneous judged by the time-scale of geological processes. Social events are more complex, but even here technical and political revolutions which may take years or days stand out as discontinuous changes against the repetitive, slowly moving background of history. Marxism in no sense ignores the slow, continuous changes; it is, in fact, quite as concerned with them as with the rapid, discontinuous ones; but it sees the continuous changes as periods of accumulation and preparation for the discontinuous, and it emphasises the impossibility of any change, leading to the fundamentally new, arising without discontinuity.

It is only a critical analysis of the facts and their relevant associations that reveals the actual conditions which lead to discontinuous change. This analysis was applied by Marx and Lenin to the economic and political development under capitalism. Here we have a capitalist exploitation for profit leading to a form of production and distribution and political control, all of which are susceptible to gradual change—liberalism, imperialism, fascism—but through all these changes of scale and intensity of exploitation and the fundamental class

antagonism it generates remain qualitatively intact. Capitalism does not change into socialism continuously, it simply changes to more reactionary capitalism. The workers do not gradually acquire power, instead they are more deceived and persecuted than ever. The revolutionary outcome appears more and more necessary. The very nature of capitalism—production for profit—is sufficient to ensure that capitalism can never develop continuously into a system where that motive can no longer exist. Only with the seizure of power by the workers can the essentially new thing, socialism, come about. The consolidating of power, the building up of a socialist economy, the approach to communism, are essentially an extension to the work of the revolution, and have the same quality of revolutionary activity. The expropriators will not, for all the prayers of the Labour Party, expropriate themselves.

Dialectics and Prediction

It is often objected that though dialectical materialism has escaped the narrowness of mechanical materialism, it has done so only by falling into an even more untenable teleology. Because it is concerned with development in the future as well as in the past, because it lays down rules for that development, it would appear that it is only the old utopian vitalism in a new guise. But there is no more teleology in dialectical materialism than there is in the most mechanical parts of physics. Let go of the apple and it will fall: that, according to Aristotle, is because it naturally seeks the lowest place; to Newton it is being attracted to the earth's centre by the force of gravity; to nineteenth-century physicists it is losing potential and gaining kinetic energy; to modern relativistic mechanics its fall is a mere statement of its freedom from any forces; and all these are merely ways of describing observable and reproducible events. The only teleology in all this is the fact that it falls downwards, and not upwards. Now, in more complicated systems, where more than one state is possible, we can say in general that a small disturbance will either leave the system unchanged or, if the system does change, it will change into a state with lower free energy. All the teleology in modern physics is included in the second law of thermodynamics, and it is only in this sense that dialectical materialism is teleo-

logical. If a social system which is involved with the internal contradictions produced by its own development changes, then it will change in general to another system which has for the moment fewer internal contradictions. In that sense and in that sense only its future is determinate.

The Importance of Critical Events

In predicting change dialectical materialism implies two things: an internal conflict in the original state, and an event or close series of events sufficiently disturbing to make an abrupt change of state possible. Both these have their precise analogues in physical nature. The first we have already discussed, the principle of decrease in free energy; the second is a universal but very ill-defined factor in all physical change, the factor of nucleus formation. An ordinary person thinks that water boils when it is heated to 100° C.; to the scientist this implies only that the kettle in which the water boiled is dirty, as most kettles are. If the kettle is ideally clean, the water will not boil. There it is as water under conditions when by all the rules it ought to be steam. Now it is so overheated that the slightest disturbance, speck of dust or tremor will set it boiling, no longer quietly, but explosively, all at once converted into vapour. When water boils normally small bubbles of steam form in it and grow and come to the surface and burst. But if the bubbles are smaller than a certain size, instead of growing larger they grow smaller and disappear, and so, without the aid of something to make bubbles, water can never boil; for boiling it needs nuclei. The same is true of any violent change: no chain can break unless there is somewhere some flaw to start a minute crack. These indispensable nuclei which initiate all changes are in detail quite unpredictable. We cannot tell until the thing is strained where the crack will first appear, but the experience of the practical man is here a better guide than the ideal picture of the scientist. He may not know where the break is coming, but he knows that sooner or later a break will come, and as far as he is concerned it does not matter where. So it is with the changes in the organic and social world. Here when the nuclei are individual, critical, historical events, a blow, a love-affair may appear as the starting-point of the most important political and social trans-

formations. It is easy to see in these cases that the transformation would have taken the same essential course if it had been started by any other chance event, and that although no theory can predict precisely when or how the critical spark will appear, it is bound to appear sooner or later.

The Role of Individuals

It is more difficult when the original impulse is given by conscious human action of an outstanding man, because here the man may have two functions: the first in preparing for the breakdown of the system he is out to destroy, the second in taking decisive action at some particular moment. It is often said that materialism is a theory that denies the importance of individual men and their actions. The relations of Lenin to Marxism and materialism are enough to refute that. Men of the calibre of Lenin do not recur very often in human history; when they do their actions are bound to have a disproportionate effect; but no one, least of all the man of remarkable genius, can set himself across the course of development of his time. Lenin had in the first place to belong to the revolutionary movement, to be influenced and moulded by the tradition of Marxism, before he could himself by his efforts and his unswerving hold on the essential elements of communist policy take such an overwhelming part in seizing and maintaining power for the first Workers' Republic. It is because of the unpredictable individuality of great men in the first place, and of their necessarily being part of contemporaneous movements in the second, that their effect can in the long run be statistically neglected. Dialectical materialism cannot and does not claim to predict the times and details of events; it only claims to show that the general trend of political developments cannot run counter to the economic forces, and these in turn counter to the more unconscious development of science and technics.

The Unity of Theory and Practice

If dialectical materialism were merely a way of explaining the world, it would have been accepted long ago as one—an important one—of the various philosophies from which an

intelligent man could make his choice. But Marxism has from its very inception been much more than this. From the dialectical point of view thought and action form an inseparable unity. The economic analysis of the history of thought shows that in fact this has been so for the positively advancing forms of thought and action—that is, in science and technics, where knowledge is in close contact with material and social realities. But wherever class societies have arisen there has always existed a group of people whose function was to produce thought without action—the priests and, later, the philosophers. For the most part, not always consciously, their function was to cloak over the inequalities of wealth and power in society by mythological or metaphysical theory, and, because they were attached to and lived on the wealthy, they acquired for the method of abstract thought the prestige that attaches to wealth and power. This prestige lasted not only through the classical civilisations, but also through the Renaissance. Pure thought changed its form from primitive religion to philosophy, back to Christian religion, to philosophy again, but it remained just as pure, just as apparently unrelated to practical activity. Its only contact was through the precepts of moralists, where it merely reinforced existing customs and added new sanctions to the secular use of coercion. Marx saw through this. The proletarian commune which he was striving to found could not remain tied to the pure thought which is so essentially a part of the bourgeois state whose disintegration he foretold. It was the workers, the industrial workers, who gave him the model of the unity of thought and action. There it was exercised unconsciously as a craft showing individual achievements but very slow traditional gains. Marx strove to make it conscious and scientific; that is why his socialism differs so essentially from that of his predecessors, and that is why it is always a sign of misunderstanding and of a leaning towards reaction when critics and revisionists wish to separate the dialectical materialism of Marx from his political programme.

Dialectics and the Class War

It is not only that the movement of the proletariat to overthrow capitalism and to found a new communist state acquires coherence and definiteness of aim through dialectical material-

ism. But any real knowledge of dialectical materialism itself implies active participation in this proletarian struggle. And here again many who have not examined or will not understand consider that Marxism ceases to be a science, and becomes a religion. But the action of the Marxist is not undertaken as the result of a mystical or emotional appeal, or strengthened by mythological forces and hopes. The problem of action is merely the reverse of the problem of teleology—the development of the future, foreseen in the conflict of the forces in the present. He does not see those forces as spirits of history external to himself, he sees them as the result of all individual human desire and efforts, of which his desires and efforts are as essentially a part as any others. If changes have come about in the past, if changes will come about in the future, it will only be because individual people have acted to bring them about. They may, and for the most part will, act unconsciously. The events of the future do not come to them as blind fate, but partly, ever so little, as the result of their own efforts.

Revolution

And so based on reason, although enthusiasm and heroism may be added, the understander of Marxian dialectic must needs take his place in the struggle for the proletarian revolution, and when it is achieved, for the building of communism. It is in this latter stage, as exemplified by the experience of the U.S.S.R., that we can really see the dialectic in its clearest form applied in practice. The economist critics pointed out the problem to them absolutely insoluble, of conscious regulation of the whole network of political, social and economic processes which have been left to unconscious chance and private greed in all previous forms of society. And yet this impossibility has been achieved, and we have the picture of that part of the world where the dialectic is consciously used overcoming all its original disadvantages and moving to greater and greater achievements, while the rest are sinking into greater and greater economic distress and political reaction, with nothing to hope for and much to fear.

After the Revolution

The final objection to the dialectic is that it destroys itself, that the crowning illogicality of Marx is postulating that, whereas all previous states destroy themselves by their internal contradictions, communism—being immune from these contradictions—is itself the exception to the whole dialectic process. The plain answer to this is to get communism first, and argue about it afterwards. But that will not satisfy the philosophic critics. A more complete answer, but essentially the same, is that, having realised communism, the world will have reached a new phase in its development, of an importance comparable with the appearance of life or of human society. The dialectical contradictions that have occupied the previous stages were social and economic contradictions. Those that will occupy the next stage will be of a different kind. The world of communism will be a world of new liberties. The unsatisfactory compromise which is at the basis of society is that separate animals are forced to renounce, in favour of co-operation and subjection to others, their primitive instinct to seize as much as they can for themselves. It has for long been made infinitely harder by the existence of the fortunate few who seem to have the liberties of action and enjoyment denied to the many. This will be radically different under communism, where there will no longer be the possibility of believing that the very existence of society is a personal injury to the majority of its members. Mankind, now consciously unified, will be facing the task of conquering the whole universe; the new field of relevance is unified humanity and the universe, and in that field there is plenty of room for further dialectical development. But to attempt to foresee that development in detail is to fail to understand the process of dialectical development. "Man," said Marx, "does not set himself a problem until he can solve it"; but equally he does not solve problems until he has set them. The immediate task is still the achievement of the revolution. It is only in revolution and revolutionary activity that dialectical materialism can really be understood.

From *Aspects of Dialectical Materialism* (Watts, 1934)

A CENTURY OF MARXISM

The Philosophy of Marx and Engels in the Light of Today

The Bible is full of prophecies. Some were written as prophecies, others were afterwards taken to be prophetic. We know now that all the explicit prophecies were in fact written after the events they foretold. Real prophecy is the rarest of human gifts, but it does exist. We are living now in a time where predictions demonstrably made one hundred years ago are being fulfilled, and that is one reason why Marx is today coming into his own. In the Communist Manifesto, he and Engels first put forward what was then an entirely unheard-of analysis of society and predicted the fall of a capitalist society that had then not even reached its full development.

Marx belongs to our time because he foresaw it. He was enabled to predict because he not only observed the world of his time but because he analysed it and struggled to change it. His predictions have come true, not merely because they were well thought out and soundly based in theory, but because his own live and work stood as an example of how to turn that theory into practice. He was the first great philosopher who did as well as talked.

Looked at in retrospect, we can now see dialectical materialism, the philosophy of Marx, as a definite and culminating step in the great tradition of human understanding and mastery of the world. Yet because Marx, in spite of his academic training, worked outside the respectable, academic world of philosophers, economists and historians, his contribution was not appreciated or as much as noticed in the learned world in his own time even while it was everywhere making its mark on history. It is only now that we can see that the philosophers of the late nineteenth century and of the early twentieth represented the backwaters and dead ends of knowledge and that the main stream of human thought follows the direction that Marx was the first to point out. In the last few years academic philosophy, buffeted by crises and wars which it failed to predict or

explain, and unable to offer any guidance to perplexed humanity, has collapsed as catastrophically as conventional market economics. Meanwhile, not only these events but the main trends of internal development in the sciences, in history and in the humanities are all driving towards the position which makes Marxism the only acceptable world view.

In spite of this it must be recognised that any real knowledge of Marxism, as apart from vague appreciation of its existence, is still very rare, and that profound understanding of it, as demonstrated by the ability to apply it to concrete circumstances, and to develop it in relation to the changing world, is far rarer still. The presentation of Marxism in general and of its basic philosophy, dialectical materialism, still falls far short of the needs of the times. This is partly due to the very interested hostility which has kept Marxism out of all traditional centres of learning and has absolutely prevented most of the acute minds of the age from looking at it at all—Lord Keynes, for example, who criticised it as a dreary doctrine, had always refused to study it himself.

That, however, is not the only factor in the failure to expound dialectical materialism. Marxists themselves have looked unkindly, and often with reason, on most attempts to translate their philosophy into terms of that of the schools. For a hundred years Marxism has existed in a capitalist world which was apparently stable and where the immediate interests of the intellectuals lay to all appearance in the support of the capitalist order. There has consequently always been a tendency, the moment the very texts of Marx and Engels are departed from, to embark on revisions and interpretations which, pretending to make Marx more intellectually acceptable by reinterpreting certain "dogmas" and "set phrases," always turn out in the end to make it more politically and economically acceptable to the bourgeoisie by leaving out the central features of class struggle and revolution. Genuine Marxists accordingly always looked with suspicion on any reformulation of the original classics for fear that they might form the starting-point of further revisions and softenings.

It is only where the theoretical understanding could march with successful political action, as in the preparation for and in the carrying through of the Russian Revolution, that Marxism could be successfully developed in the great and new classic

work of Lenin and Stalin. It is now, when not only the Soviet Union but the whole world has been shaken by war and social transformation, that Marx's message and Marx's methods require to be most widely known and most intensely used. The study of Marx's work in the light of the present political position and its reflection in the world of thought today is the first step both to its wider acceptance and to the full possibilities of its application.

The Bankruptcy of Philosophy

The philosophic lights of the present age are burning very dim. Outside the Soviet Union there is nowhere any intellectually reputable system of thought that has gained widespread adherence and is serving as an inspiration for action. Instead we have a number of polite but totally ineffectual philosophies taught at universities, a revival of dead religious dogma and outside them a large mass of non-intellectual or even anti-intellectual beliefs, ranging from fairly harmless astrology and spiritualism to the fullest bestialities of the Nazi race theory, of which unfortunately we have not heard the last. The reason for this intellectual bankruptcy is becoming apparent even to non-Marxists. The development of nineteenth-century philosophy marched well hand in hand with that of capitalism. But the optimistic philosophers of liberalism and progress can no longer hold up their heads when the peaceful constitutional progress and increasing well-being which they prophesied has been so clearly refuted by the hard events of these last tragic years. Academic philosophy has been forced now, as in the days of the Roman Empire, to move towards abstract emptiness or mysticism.

But if the schools provide no inspiration or even clue to the difficulties of the present, they leave the field open to other forces. The churches, now setting themselves up openly as bulwarks of political reaction, are making a serious attempt to obtain an intellectual predominance by reviving the dead philosophies of the Middle Ages. In their day these philosophies were the means by which freshly awakened reason could be reconciled to the dogmas which were then already centuries old. Now they have no power even for this but serve just to dull men's thoughts and inculcate a feeling of mental impotence

with a corresponding docility towards the commands of their spiritual superiors. This turning back finds its echo outside the churches, particularly in literary circles, in the vogue of philosophies of pessimism such as that of the existentialists, or of absolute cynicism which sees no good in anything and no hope for anything.

The fading away of official philosophy within the last twenty years deserves a competent and detailed study. That it has faded away there can be no doubt at all. A review of present thought shows only a few relics of what were once powerful systems of belief. The war, virtually closing the arts faculties in the universities—by necessity in the unoccupied countries and by force in the occupied—had the effect of turning away what little interest remained in official philosophy. In the occupied countries the close contact with the realities of collaboration or resistance forced men to take philosophy more seriously, but did not lead to a revival of official philosophy: rather to a new interest in Marxism on the one hand and of mysticism and existentialism on the other. It is only in England and the United States that any continuity has been preserved; even there, however, the needs of a war-strained people for a philosophy have not been met. This is essentially because the official philosophies, in which we can distinguish a logical and positivist branch, have long ceased to concern themselves with questions that men really care about and, in fact, actually pride themselves on not doing so.

Logic

The logical development, which owes its original drive to Bertrand Russell—and still flourishes in a minor way in Cambridge and some of the more conservative American colleges—has succeeded in proving to the satisfaction of its adepts that philosophy is only concerned with precision of expression—"in being clear about being clear about being clear" as Professor Moore has put it. Bertrand Russell himself in his *Outline of Philosophy* complains that the ordinary man's view of the world is cocksure, vague and self-contradictory, and states that the function of philosophy is to make it tentative, precise and logical. The process of doing so has turned philosophy into a kind of superior grammar, so pure and precise that its adepts have regretfully come to the conclusion that anything more

complicated than a three-word sentence is beyond human power of understanding. By rejecting from philosophy any but purely formal elements they have of course from the outset prevented philosophy from having any effect on human beliefs and human affairs; but they have not even succeeded in the more restricted aim of assisting in clarifying the basis of scientific knowledge so as to enable present theories to be verified and future ones to be discovered. As far as I know not one single, even minor, scientific discovery has followed all the work of the logical school of philosophy. Its own self-denying ordinances have doomed it to complete sterility. As Wittgenstein says in the last thesis of his famous book,[1] "Whereof one cannot speak, thereof one must be silent."

Positivism

The other school of philosophy, which originated in Vienna, and seems to have established itself most firmly in the United States, is that of neo-positivism. From the outset more closely related to science than was traditional philosophy, the neo-positivists have made the attempt to distinguish what can be stated in a verifiable way and what is mere verbiage. It was thought for some time that this was a matter of choosing a correct language, and the search for a language in which only sense could be talked was one of the positivists' main preoccupations. But this search led only to endless paradoxes. While the logicians wisely avoided having any words at all in their language and took refuge in an abstruse and empty symbolism, the positivists sought to form a vocabulary of reliable and real things with which to begin making more complete statements. But this "protocol" language could never be agreed upon, and the vital question as to whether what they referred to were things or bundles of sensations could not be resolved in positivist terms. The first answer led to materialism and hence, under modern conditions, to dialectical materialism. The second led inevitably to solipsism and mysticism in the way diagnosed by Lenin in his criticism of the positivism of Mach.[2]

[1] *Tractatus Logico-Philosophicus* (Kegan Paul, 1933).

[2] See V. I. Lenin, "Materialism and Empirio-Criticism," *Selected Works*, Eng. ed., vol. xi (Lawrence and Wishart); Max Black, "Evolution and Positivism," *Modern Quarterly*, January 1938; Barrows Dunham, *Man Against Myth* (Muller, 1948); Bertrand Russell, *History of Western Philosophy* (Allen and Unwin, 1946); Maurice Cornforth, *Science Versus Idealism* (Lawrence and Wishart, 1946).

The essential weakness of the positivists' position—which they shared with the logicians—was the deliberate avoidance of any contact with social and economic realities. By labelling everything which had no direct expression in terms of the natural sciences "metaphysical" and subject only to emotional judgment, they cut themselves off from the fields in which the most decisive actions of the time were taking place.

Common-sense Philosophy

In England, however, and to a large extent in the United States also, academic philosophies have never counted for much, and the great majority of thinking Englishmen or Americans would probably have said if questioned that they had no philosophy and never felt the need for having one. This, as Engels pointed out many years ago, did not mean that they did not have a philosophy, it only meant that they did not know that they had one and that they accepted and acted upon a mixture of old and usually bad philosophies and called it "common sense."[1] The basis of popular philosophy was dualism. People believed, though they would hardly state, that the world is divided into two parts, a material part in which the laws of nature are rigorously obeyed—or at least can be trusted to behave properly for practical engineers or chemists—and a non-material world composed of traditions and values and, for those who wanted them, gods, spirits and religious experiences as well. The boundaries of these two worlds were not very clearly defined. It was never certain, for instance, whether economics referred to the material world and was a matter of iron laws, or whether it was the applied psychology of successful business men.

The great advantage of anti-philosophical philosophy, or what we might call phobosophy or fear of abstract knowledge, was that it enabled you to take the world exactly as you found it and adapt yourself to it to your own best advantage. The reasonable part of the world took you just as far as you needed for practical purposes: on politics or religion there was no need to argue; agnosticism or faith were equally acceptable as long as they did not interfere with business. The central practical weakness of this common-sense view was that it was incapable of dealing with changing circumstances. It made its adepts,

[1] See page 361.

however well qualified in academic, business or political circles, completely blind to the vast economic and political changes in the world that led up to the present war, and unable to cope with the conditions of war when they came. Such philosophy can of its very nature generate nothing new. In the hands of a scientist it still can be used to grind out particular results, but not to see that science is organised for the community. In the hands of business men it can look after the interests of the firm until the firm itself is wiped out by a slump the cause of which is outside their ken. In politics its natural expression was before the war the appeasement of fascism; now it is the doctrine of—anything rather than communism.

Anti-intellectualism

The bankruptcy of academic philosophy in latter-day capitalism has opened the door to the very opposite of all philosophy—magic, mysticism and superstition. Though already noticeable before the first world war, openly anti-intellectualist views spread most rapidly in the years between the wars and provided everywhere the ideology for fascism in its clerical or pagan forms. One step beyond refusing to think at all about social problems is to think about them mystically in terms of souls, bloods and races; to say that no solution can be looked for in hard thinking and straightforward experimentation, but rather in mystical exercise and listening to the frenzies of heaven-sent leaders. Intellectual decadence has never gone further than it did in those days because all earlier nonsense of this sort had the excuse that nothing better was known, while the mysteries of old times were the natural traditional outgrowths of social and economic customs. The new mysticism, however, is synthetic and deliberately fostered by a few to distract the many from any understanding of social defects and to make them into willing tools of reaction, with what hideous and tragic results we have just witnessed.

Against these tendencies nothing in official education or official philosophy could be effective. Not being intellectually vigorous or intellectually honest themselves, the official guardians of culture could not meet the immediate appeal of the greater dishonesty. As Hitler first pointed out—it is the big lie that people believe. Fascism has suffered a military

defeat, but the ideas and feelings behind it are still alive and potent. It is idle to hope that those who, before it became too menacing tò their interests, saw no harm in it should, once these were again secure, be anxious to eradicate it. The danger now is that anti-intellectualism, no longer concentrated in Germany, is spreading all over the areas of so-called Western civilisation. It can take many forms, from aggressive clericalism and atom-bomb militarism to the mild but dangerous pessimisms of Kierkegaard and Sartre. All these forms have something in common. They all express the belief that man's state cannot be improved by conscious intelligent co-operation. They want less knowledge and more faith and are unanimous in attacking the countries where men are trying to build up a scientific civilisation through their own efforts, and in belittling the beliefs which are leading them to do so—the philosophic system of dialectical materialism.

The Character of Dialectical Materialism

In these times of intellectual decay the philosophy of Marx stands out firm and flourishing. On account of its origin and character it has been immune from the disintegrating forces that have destroyed other forms of human thought. For it is reasonable and scientific: it is comprehensive: it is a philosophy of change for changing times: it is a philosophy of action and not of contemplation, of hope and not of despair; and last and most important, it is the philosophy of the working class.

Rationality

Marx and Engels, Lenin and Stalin have carried on the tradition of rational and non-mystical approach to all human problems; this is the tradition of the best Greek philosophers and the founders of modern science. Careful analysis; separation of factors; the following of causes into their effects; reliance on experiments: all are taken over into Marxism and provide it with a hard scientific core. There is nowhere any pandering to special intuitions or spiritual experiences. Engels' delightful treatment of spiritualism in the *Dialectics of Nature* and Lenin's sober and serious discussion of religion[1] show in their different

[1] *Lenin on Religion*, Little Lenin Library, No. 7 (Lawrence and Wishart).

ways how free Marxism was, and remains, of the dangers of emotional blindly traditional thinking.

Comprehensiveness

This does not mean limiting philosophy to mere natural fact—that was the mistake of the old materialists. On the contrary, the essence of Marxism is that while it remains firmly based on the material universe, it includes the whole range of human experience—the past as well as the present. It deals with society in its productive relations; with the economic and legal forms which have grown out of these relations: and with the whole ideology of science and art and religion, that forms the superstructure of the productive and economic life of society.[1] By relating all these together and by ceaselessly reviewing their relations throughout changes which society undergoes, and never more rapidly than now, it has a comprehensiveness no other philosophy has ever approached.

A Philosophy of Change

The ages in which great philosophies or religions have appeared have all been ages of intense social change. The India of Buddha, the China of Confucius, the Greek cities before Socrates, and the Syria of the first century were all in a transitional change between different social groupings. The great seventeenth century, the age of Descartes and Newton, the beginning of the triumph of capitalism, was just such another period. Nevertheless, until Marx all philosophic and religious originators conceived an ideal philosophy fitted for an ideal, static civilisation. They saw the evils of their times and

[1] As it was first put in the Communist Manifesto:

But don't wrangle with us so long as you apply, to our intended abolition of bourgeois property, the standard of your bourgeois notions of freedom, culture, law, etc. Your very ideas are but the outgrowth of the conditions of your bourgeois production and bourgeois property, just as your jurisprudence is but the will of your class made into a law for all, a will whose essential character and direction are determined by the economic conditions of existence of your class.

The selfish misconception that induces you to transform into eternal laws of nature and of reason, the social forms springing from your present mode of production and form of property—historical relations that rise and disappear in the progress of production—this misconception you share with every ruling class that has preceded you. What you see clearly in the case of ancient property, what you admit in the case of feudal property, you are of course forbidden to admit in the case of your own bourgeois form of property.

strove to hold them back by an appeal to the better social traditions of a stabler time. Even in the seventeenth century, reformation rather than new creation, return to reason rather than achievement of new things, was the dominant note.

The philosophy of Marx was the first to acknowledge explicitly the permanently changing nature of human relations and the way in which that change manifested itself in violent revolutions. Marxism does not ask for a return to any ideal state of the past, but demands that men shall understand enough to build and keep on building new social forms for themselves in the future. It differs from the vaguely progressive liberalism of the nineteenth century by its deeper analysis which shows that progress cannot be taken for granted. It shows it to be due to the interaction of economic and social forces operating through consciously directed human wills.

A Philosophy of Action

In this respect also dialectical materialism is new. In the classic phrase of Marx: "The philosophers have only *interpreted* the world in various ways; the point, however, is to *change it*."[1]

In Marxism, for the first time, thought and action are revealed as inseparable. Philosophers of old have dreamt of philosopher kings, but they themselves have never claimed to act. Religious fanatics have acted, but thinking was not their strong point. The first union of thought and action in a quiet way was that of the experimental philosophers who founded modern science, but their action was severely limited to the natural world, or, as the draft statutes of the Royal Society have it, "not meddling with Divinity, Metaphysics, Moralls, Politicks, Grammar, Rhetorick or Logick."[2]

Marxist analysis shows, in conformity with modern psychology, that pure thought is only a kind of aborted action. Philosophers, economists and sociologists have found it convenient in the past to forget this, because some of the actions their thoughts might have indicated would not have been pleasing to their patrons or employers. Marx, however, showed in his life as much as in his writings that any valid social theory

[1] Frederick Engels, Appendix to *Ludwig Feuerbach*, Thesis XI on Feuerbach, written 1845.

[2] Manuscript volume of Hooke's papers dated 1663.

implies positive and conscious action by its adherents. Dialectical materialism is a philosophy of action—not of the interested or denuded mystical action of the fascist, but of the carefully weighed, thought-out and timed action of the scientific socialist.

A Philosophy of Hope

It is this combination of knowledge and action that makes the philosophy of Marx predominantly a philosophy of hope. That hope is not a mystical one, nor one founded on that belief in an automatic deliverance through the operation of an inevitable chain of causes that is so often mistakenly attributed to Marxists. Hope is based on experience: the experience of more than a hundred years of bitter, often defeated, but ever more successful struggles. Marx gave men a new understanding of the relation of social forces. In the light of that understanding they have known how to work with these forces and not against them, and they have acquired an unlimited hope that, acting together, they will pass through the critical and transitional time that marks the passage from capitalism to socialism.

The Philosophy of the Working Class

Marxism is first and foremost the philosophy of that section of society which alone can initiate and carry through the only positive hopeful and creative changes at the present time. It is the working-class philosophy. In the beginning it was learned from the working class and nurtured in the working-class movement.[1] Its rise to importance in the world coincides with the rise in importance of the organised working class itself. In the development of large-scale mechanical and ultimately of scientific industry, Marx and Engels saw the beginning of this process. They saw how the very economics of capitalism produce crises:

> And how does the bourgeoisie get over these crises? On the one hand by the enforced destruction of a mass of productive forces; on the other, by the conquest of new markets, and by the more thorough exploitation of the old ones. That is to say, by

[1] "Learned from the working class" does not mean produced by the working class; cf. V. I. Lenin, *What is to be Done?*, Little Lenin Library, No. 4, p. 32. (Lawrence and Wishart).

> paving the way for more extensive and more destructive crises, and by diminishing the means whereby crises are prevented.
>
> The weapons with which the bourgeoisie felled feudalism to the ground are now turned against the bourgeoisie itself.
>
> But not only has the bourgeoisie forged the weapons that bring death to itself; it has also called into existence the men who are to wield those weapons—the modern working class—the proletarians.
>
> In proportion as the bourgeoisie, i.e. capital, is developed, in the same proportion is the proletariat, the modern working class, developed—a class of labourers, who live only so long as they find work, and who find work only so long as their labour increases capital. (Communist Manifesto)

The open triumph of the proletariat began with the successful revolution and the building of socialism in the Soviet Union, and was assured in the heroic defence of the Union which saved Europe and the world from fascism. It was a working-class philosophy, not in the exclusive but inclusive sense. Those who accept and act it—for the two are synonymous—are automatically themselves part of the working-class movement. But in another and longer view it is not limited to the working class; the state it aims to achieve is the classless state, and it has already shown in the Soviet Union that the philosophy of dialectical materialism is not the philosophy of one section but of the whole people. It inspires them, it holds them together, it gives them an intelligence and a strength, it is a weapon in war and peace more powerful than anything physical science can invent. As the philosophy of the working class, it is the philosophy of the people of the world of the future.

The Content and Method of Dialectical Materialism

The characteristics of Marxism that have just been outlined, its rationality and comprehensiveness, its emphasis on change and action and its attachment to contemporary struggles, are the external expression of the philosophy of dialectical materialism. But dialectical materialism has an inner content and method of its own, both of which are well worth studying, though the method cannot be profitably abstracted from its content but rather must be demonstrated as implicit in it. As Lenin said: "In what work has Marx not set forth his materialist conception of history?"[1] The content of Marxism,

[1] *What the "Friends of the People" Are*, Lenin, *Selected Works*, English ed., vol. i (Lawrence and Wishart).

its source of factual beliefs, derives from the great liberal tradition of the seventeenth and eighteenth centuries—the tradition of scientific inquiry and resistance to religious and philosophical dogmatism that were associated with the names of Newton and Voltaire; as it was also the tradition of the early economists of the French, Scottish and English schools, the economics of Quesnay, Adam Smith and Ricardo. With such a background alone Marx might have been a liberal; that he was something far greater was due to a combination of two things, to the deep influence of the historical and philosophical school of Hegel, which prevented him from accepting the liberal world picture as a somewhat static, natural order of things which had merely been perverted by wicked priests and kings, and to his immediate participation in the revolutionary struggles of the forties which showed him how much the liberal economic picture hid the brutalities and destructiveness of early capitalism. On the other hand he could not accept the original Hegelian view that "all that is real is rational and all that is rational real" for he had seen beyond the artificial and limited class outlook of the professional Hegelians with their worship of the Junker-bourgeois Prussian state.

The Objective World

The content of Marxism is a balanced and active knowledge of the totality of the objective world; a balanced knowledge because from the beginning he recognised that the elaboration and complexity of a system is more important than its mere size. Though he never neglected the physical sciences, he saw them as far simpler disciplines which underlay the ever increasing complexity of organic life and human society. Physics and sociology were both means of describing one real, self-moving and self-changing world. The unity of the universe, the close and necessary connection between objective and subjective, between life and non-living, between human nature and society, was fundamental. Where other philosophers, particularly scientific philosophers, fell into a dualism and separated mind and matter or facts and values, he insisted that such separations were simply a running away from problems that had to be faced and tackled. This oneness was not itself —as it appeared to monistic philosophers—simply another

dogma, a flattening out of experience to fit into a preconceived pattern. It was on the contrary intricate and complex. It was the totality of the relations binding the whole universe together in space and time. Every part of the universe was at the same time the resultant of all that had happened before and the source of all that was to happen afterwards. The Marxian unity does not deny the differences between the things and the processes that make up the universe: these very differences are themselves part of the unitary process of differentiation. Change is implicit in existence. The Marxist view, however, is equally removed from the pluralistic. The universe is not merely a shifting and changing chaos; it shows a sequence of orders of phenomena, each order derived from the previous one and including its phenomena in itself.

The significant dialectical changes in the universe were those which led step by step to the production of fundamental distinctions of order of complexity between different parts of it—between stars and animals and human achievements. Marx, long before Darwin, was a firm evolutionist; for him the world was a process and not a mere collection of things; but he was not happy in simply noting the fact of evolution, he wanted everywhere to see the fundamental reasons for innovation and change. He found those reasons precisely where change was most rapid and most easily observable, in the changing social and economic conditions of his own time.

The Laws of Change

The clue to the understanding he took from Hegel's dialectics; it was the content he gave to that clue, it was the way in which he understood the stages of capitalism and the next stages of its development, that make Marx rather than Hegel the real philosophical originator. The clue itself is that a process cannot in a real world continue unchanged in any direction, that it inevitably brings with it counter-processes and that the counter-processes, uniting with the original process, produce the true novelty or next stage in development. This is the central core of the theory of dialectical materialism. The fact that it was found first in the social sphere does not make it any the less valid for the underlying biological and physical stages of evolution; It is, however, necessarily more difficult to observe,

and it is only now coming to light in the modern theories of organic and cosmic development (see below).

From this concept of dialectical change stem the other forms which Marx also borrowed from Hegel, giving a rich and solid content to what were before empty abstractions—the unity and interpenetration of opposites, the negation of the negation, the transformation of quantity into quality. These phrases are valuable because they enable us to comprehend simply a multitude of actual instances and because they represent something common in real processes differing in most other particulars. They are natural laws, but natural laws different in kind from those met with in physical science because they are the laws of change and not of conservation, they represent probabilities and not certainties.[1] They are actually excluded from the realm of natural science by the older definitions which made an axiom of the regularity and order of nature and did not concern itself with the changes in that order, changes which, as far as physics and chemistry go, were until recently quite unobservable in terms of human experience. By the same reasoning social phenomena where order did not reign were outside the scope of science and only a matter for the vague platitudes or emotional evocations of history, philosophy or ethics.

By concentrating on change and the mechanism of change, Marx's work had both a positive and a negative aspect. Positively, in the political field it was only through understanding how changes happen and how new things come into the world that the working class could learn to understand what was their historical function, how they could now discern clearly and rationally what was to be done. Negatively, in religion and philosophy it destroyed the very foundations of dogmatism and authoritarianism. It made men feel free because it showed them how and where they were bound. A world in which the order was one established by God, or

[1] In recent times the development of physics has shown that many of the uniform laws which it propounds, such as Boyle's Law, are in reality due to the chance interplay of a multitude of particles: they are statistical laws; but such statistical laws are still different from the laws of dialectical change in that, from the very number of co-operating particles, the gross external results are always predictable: the probabilities are nearly always unity. It is only when the number of units is very small or when the system is in a state of peculiar instability, as in the case of so-called critical phenomena, that unpredictable changes can occur. Therefore, it is only when such a system is so influenced by such a fortuitous change that it cannot revert to its previous state that anything new and stable is produced.

by which the change was the function of God's providence or of an even vaguer general purpose, was a world where knowledge was fixed and authority had to be accepted. If God made the world and God preserved it and changed it, then God must be obeyed and so must his agents on earth, the priests, the rulers and the wealthy. We now know that this conception of the universe is a human rationalisation which has grown up and has been transformed with the transformation of society. It reflects that unequal division of society between the exploiters and the exploited that Marx was the first to point out and explain. Eternal values, the existence of which is always held up in the support of reaction, are eternal for that very reason. As the Communist Manifesto has it:

> The history of all past society has consisted in the development of class antagonisms, antagonisms that assumed different forms at different epochs.
>
> But whatever form they may have taken, one fact is common to all past ages, viz. the exploitation of one part of society by the other. No wonder, then, that the social consciousness of past ages, despite all the multiplicity and variety it displays, moves within certain common forms, or general ideas, which cannot completely vanish except with the total disappearance of class antagonisms.

Simply to denounce traditional views of the universe because they were not true or because they justified tyranny and oppression, as did the eighteenth-century rationalist liberals, was not enough. Men need some reasonable or at least plausible picture of the world they live in and they will not give up the old picture, however irrational, unless the same questions to which the old dogmatism had ready answers can be reasonably answered or shown to be meaningless in the new system. This is just what Marx did. Not that he gave a detailed answer: not that he claimed to be able to show precisely how every stage in evolution or every social change took place when and where it did; but he did point to the contradictions and the struggles that led to these changes, and he did show how these contradictions and struggles in turn arose from the aftermath of previous ones. He showed where we must look for an answer and how in that search we can acquire deeper understanding of the past and more effective control of the future.

Dialectics and Common Sense

The dialectic aspect of Marxism is the one which has raised the greatest difficulties to its acceptance in scientific circles, particularly in countries with the English empirical tradition. It was considered both unnecessary and offensive. The whole tradition of English thought since Bacon's time has been practical and anti-philosophic. It has been marked ostensibly by common sense and attention to detail with an avoidance of speculation and philosophic generality. In fact it has been violently dualist: shrewd and practical in material things, loose and sentimental in social and metaphysical thinking. The unity of opposites or the negation of the negation, the Hegelian triad of thesis, antithesis and synthesis seemed so much unnecessary intellectual baggage. Even socialists have often expressed a desire to have Marx without the burden of his dialectics. Yet these dialectic categories are rich in content and powerful in action. They are, so to speak, pointers or ways of looking at concrete situations which serve to bring out elements in them which otherwise remain obscure or confused. Nineteenth-century historians were able to paint brilliant pictures of the life of their times, but because of their lack of such guiding threads they were never able to make any coherent sense out of their pictures.

Marx did more than describe the dialectic pattern of the universe—and his historical descriptions are among the best of his time—he interpreted. His interpretation has not only stood the test of time but has given us the clue to the analysis of present-day problems. Dialectical opposites were never for Marx mere figures of speech or even abstract ideas, as they were to Hegelians. They represented real things, really working against each other: the capitalists and the wage-earning workers: the feudal lords and the merchants. Engels followed in *The Origin of the Family* and in *The Mark* the same ideas back to the struggle between the land-owning nobles and the clans and still further to the very origin of humanity itself, in the struggle between the greedy individual animal and the socially collaborating group.

One may notice in this pattern, in which each dominating form is struggling against that which gave birth to it, the regular alternation of individual to group and group to individual.

Yet the individuals at the different stages—the ape, the barbarian, the noble, the individual capitalist—are not the same. The individual reappears at each new stage in a new form, a form which includes the moulding influence of the new collective. It is something on a higher plane—the negation of the negation. That the move is to a higher level is not accidental. It is because in each transformation the results of the previous transformation are carried over and added on to. We embody in our social tradition the basic elements of all the traditions which have preceded us just as we inherit in our bodies the organic evolutionary transformations which preceded the social ones.

Dialectics of Nature

Below the human level lie other great struggles and great transformations. Marx did not concern himself with these much in his published work, but his letters show his keen interest in them, and Engels in his *Dialectics of Nature* points out some of the more striking ones, such as the origin of planetary systems and of life on this planet. We now see, thanks to Marx and Engels, the whole of the vast history of the universe as a series of transformations from stage to stage. These stages form a hierarchy or ordering of complexity, each one including all the complexities of the stages that went before and adding to them its own specific order of complexity. The laws of chemistry, for example, hold for all the higher stages as in the chemical transformations that go on in living bodies. The individuals in human society are animals for whom all biological laws hold.

Marx was not the first to see that the simpler phases always preceded in time the more complex ones: that the hierarchy of complexity is always a sequence in evolution, but he saw further than his predecessors and most of his successors. He saw that in moving from one stage to the next there is always something more. There is more in chemistry than in physics, more in biology than chemistry. What is that something? That very form of the question breeds a deceptive answer. The kind of answer that satisfied early man was that a spirit or breath of life was what distinguished man from clay. This is also essentially the view of the modern academic philosopher, who attributes new forms to an entelechy or principle. With

Marx the difference was not a "thing," a new substance, or even an emergent order. The difference was intrinsic, it arose from the very multiplicity and complexity of the earlier state itself. Even if you merely keep on adding more of a substance, sooner or later it will become something else. Enough grains of sand will become a dune;[1] the agglomeration of cells an animal; quantity will be transformed into quality. It was in such a way that the multiple ritual exchanges between primitive villages became that system of trade which in turn gave rise to towns. A town is a big village but it is also something more and new. Thanks to its very size some portion of subsistence can be set aside for specialised workers of no immediate economic utility—goldsmiths, artists, poets and philosophers; but the town also generates, for the transaction of its business, a new and higher organisation which could never appear in the village—the markets, the banks and the magistracy; in short, all that we very properly call civilisation.

This view of the history of mankind as a series of changes of order is of course in itself a very old one. The myth of the ages of gold, silver, bronze and iron must have started at the very time when some of the greatest of those changes was occurring. What Marx added was the much broader sweep of the generalisation and the much closer analysis of the critical transformations which separated the different levels. In addition, the world view of Marxism makes it impossible any longer to confuse these stages. It shows what is specific and new in the

[1] It may be objected that to say a number of grains of sand become something different, such as a dune, is merely a verbal statement—that we choose to call a number of grains of sand a dune, just as we call a number of units a thousand or a million. Such objection occurs naturally to people educated in abstract thinking. If we put grains together in abstraction, all we will get is more and more grains of sand, but if we put grains together in an actual world, after the first few they start piling on each other: their relations are no longer only conceptual but physical, and the pile, in response to its support and to gravitational forces, acquires a definite shape with its own laws. Adding more and more in a real world we get an interaction with the wind: the shape of the simple pile is modified: it becomes a dune with new laws of its own—it grows, it develops a sharp crest dividing lee and windward sides, it moves, it combines with other dunes to form dune systems and sand deserts. Now to this it may be objected that we are not really talking about grains of sand at all, we are talking about grains of sand with a supporting surface subject to gravitational forces and to wind pressure; but those other things were there anyhow; it is only the quantity of the sand that makes the difference. All transformations of quantity into quality involve a complexity of change in relation to internal and external environment. For instance, with a finite number of any kinds of objects, some will be on the inside of the collection and others on the outside; with this in a real environment the outside ones will be subject to different conditions from the inside ones; they will be modified, and thus a crust and skin with special properties will develop.

complexity characterising each stage. It thus makes intellectually impossible both the old naïve appreciation of the world of nature in terms of human society which we call anthropomorphism and which still persists in our religions, and equally the more modern form which tries to explain human affairs directly in biological or physical terms. This is the heresy of "biologism" fathered on Darwin and which found such a ghastly expression in the murder camps of the Nazis. The Marxist sees clearly what belongs to each grade of the hierarchy and, further, what kind of language is proper to its description.

All the basic concepts of Marxism—the unity of opposites, the negation of the negation, the transformation of quantity into quality—are not separate and independent. They all, as examples here show, fit into one another to make one complex but now understandable pattern of change. To have and to hold such a picture—even more, to use and to test such a picture in working life—is in itself another human transformation. The achievement of dialectical materialism is essentially part of the achieving of a consciously planning, classless human society.

Revolutionary Change

There is one other crucial aspect of Marxism whose form is not derived directly from Hegel. This is the sharpness of the conflicts and transformations by which new things come into the world. It is not that Marx did not recognise gradual change but he saw that gradual changes ultimately lead to critical situations where change could no longer be gradual and a definite break has to occur. These breaks he saw in the social field as economic and political revolutions. For example, in England, all through the sixteenth and early seventeenth centuries, the growing bourgeoisie spread their adventures and piled up their profits; but the conflict with the older order of society which this process made inevitable could not occur gradually, it took the form of civil war and revolution.

The reason for the inevitablity of ungradualness is that any state or order in the world must be a self-consistent whole; it must unite economic practices, institutional forms, ideas and feelings. One part cannot be changed without involving the rest. But the whole has rigidity; it cannot bend and must

break. Marx saw social change occurring not by gradual transition but through the necessary appearance of new systems inside the old ones. These new systems at first existed as part of the old, building up their own internal constitutions through the creation of new ideologies. The old and the new are never distinct; while in opposition they continually react on one another; but the old does not transform into the new, it is rather that the new breaks apart and shatters the old. Sharp transitions were not confined to human affairs; the whole of organic evolution, with the appearance of new dominant classes such as the mammals and, before that, the distinction of solid, liquid and gas, are examples of the abrupt breaks or nodal points which separate both in time and order of complexity the different parts of the universe. Dialectical materialism, while insisting on wholeness of interreaction, equally insists on distinction and abrupt change.

Materialism

The philosophy of contradiction and transformation was the philosophy of Hegel. The difference that Marx made to it was not merely in clothing its abstractions in concrete examples from society and nature; it was in totally reversing it. Marxism was from the start on a material basis—and this is not quibbling about the nature or the reality of matter. It is a standpoint in philosophy which accepts the apparent universe, the universe we know and use, as the first thing. Our own thoughts and feelings must be derived from that universe. This view rejects the shadow show of idealism in which the universe is a dream and an illusion which logically ends up with the purely private world of the solipsist to whom even other persons are the creation of his own fancy. Marx does not try, as Hegel did, to evolve the world logically from one idea. Instead he accepts the world and proceeds to find out how it works and how to work it. In finding out how the world works we do in fact through science discover that animals existed before man and that a lifeless world preceded life. But there was before Marx's time, and there still is outside the range of Marxism, a reluctance to admit that the very thoughts and feelings of man are themselves resultants of biological and

ultimately material processes, that "the beginning was the fact" and not the "word."

Materialist dialectics is something, however, as different from older materialism as it is from the idealist dialectics of Hegel. The older materialism was heavily influenced by the early achievements in natural science, in establishing rigid and eternal laws. It was perhaps most clearly seen and almost reduced to absurdity by Laplace, who claimed that if we knew at any time the velocity and direction of every particle in the universe, it would be possible not only to determine all their past movements but all their future movements to eternity. Modern quantum mechanics has shown that it is not only mentally but physically impossible to determine the motions of all the particles at any moment; but long before, Marx had criticised this viewpoint on the grounds that there was more in the universe than the motions of particles, that higher orders of complexities had quantities and laws of their own, and that new complexities and new laws for them to follow were being continually generated. The materialism of Marx is not an automatic determinism. It is a continual redetermination with unlimited and, in detail, unpredictable possibilities.

Dialectical Materialism in Modern Thought

Dialectical materialism first appeared effectively to the academic and so-called intellectual circles outside the Soviet Union hardly more than twenty years ago. Even the economic aspects of Marxism which were best-known had always largely been ignored and resisted both by the academic economists and by the official labour movement. The more philosophical and intellectual parts of Marxism were only studied by a small handful of people and only came into prominence largely as the result of the practical achievements of Marxism in the Soviet Union. There is still, for instance, no discussion of dialectical materialism in any official course of philosophy in any university in Britain.[1] The study of Marxist theory in universities was and is still largely as unofficial and as exciting

[1] It is true that a number of years ago the London School of Economics did have a series of lectures on Marxism delivered by the carefully selected leading anti-Marxists in the country, while the use of the college lecture rooms was forbidden to those who wished to expound the actual views of Marx, Engels and Lenin.

an enterprise as reading the Greek testament in the early sixteenth century or studying science in the seventeenth.

Nevertheless the official academic world has at last had to become aware of Marxism. It is now a major issue on the philosophic front and has already generated its own opposition. Although the opposition to Marxism on intellectual grounds is largely due to misconceptions, these are not accidental. It is the desire to reject Marxism on political and economic grounds that consciously or unconsciously takes the form of philosophical criticism.

The two bases of attack on dialectical materialism are, not surprisingly, themselves mutually contradictory. One is that Marxism is a mere vague set of conventional aphorisms and is no real philosophy at all, in that it makes no provable or disprovable assertion; and the other is that Marxism is a rigid and dogmatic system which claims to determine once and for all the laws of the universe, to explain its past and to predict its future. Now whatever part prejudice has in the forming of these opinions, they deserve the closest consideration because they reveal not only the attitude of non-Marxists or anti-Marxists, but also to a certain extent reflect the mistakes in exposition, and in some cases in understanding, of professed Marxists themselves.

Dialectics and Science

The first objection is, effectively, that Marxism is not scientific. Now this depends on a misunderstanding as to the meaning and scope of science. By defining science narrowly and limiting its field of operation to physical quantities that can be more or less precisely measured and to changes that are cyclical and follow eternal laws, it is possible to exclude from science, not only Marxism, but the whole study of human societies, their history, their economics and their politics; in fact social science in its entirety. Marxism does not pretend to be limited to this narrow definition of science. Marx himself maintained, and Lenin and Stalin have demonstrated, that successful prediction and successful experimentation is not limited to the physical or even the biological sciences. Nevertheless it would be absurd to expect that the precise methods of argument which hold in the first, and to a certain degree in

the second of these fields, can apply to the far more complex social phenomena. Dialectical materialism claims to be a mode of thought most suited to dealing with the events in the social field. It was built up from observations in this field and has been the basis for successful action in it.

That does not mean that dialectical materialism is simply a philosophic basis for social science and something that stands apart from natural science. Because human society includes in itself the whole biological character of the individual human beings that compose it, and in each of whom in turn the physiological processes follow the laws of physics and chemistry, so dialectical materialism does not stand beside natural science, but includes it. Natural science itself has two aspects; in relation to the world of material objects and organisms it is a summary of the methods of analysing and manipulating them, but it is also itself a human social enterprise built up by individual men and responsive to the economic and political changes of society. Science as we know it today is not an abstract product of applied intelligence, it is an integral part—product and producer—of the achievement of capitalist technology. Capitalism made science possible; science makes capitalism superfluous.

It is this social aspect of natural science that is part of the wider synthesis of dialectical materialism. Dialectical materialism enters natural science in the field of understanding, by analysing its conclusions in relation to its origins, as Engels did for instance to nineteenth-century science in the *Dialectics of Nature*. But it also enters science in the field of action by indicating how science needs to be organised and how related to economic and social forces, a process first clearly undertaken in the Soviet Union and which was copied through force of circumstances in all the nations fighting in the late war, including the ultra-individualistic Americans.

The characteristic weakness of natural science as developed in the later stages of the nineteenth and in the early twentieth centuries—that is in the period of decaying capitalism—was its inability to integrate with the social movements of the time. Just because the intellectual felt in danger of becoming a mere slave and parasite of capitalism, he tended to withdraw, or at least to pretend to withdraw, from the world: he took refuge in abstractions and over-specialisations: he prided himself on

his impartiality and purity and on his very incapacity to deal with practical affairs. This was a very convenient attitude for the intellectual, who thus was able to let the captains of industry carry on without protest, and even to profit by helping them. It was also very convenient for the captains of industry.

Dialectical materialism offers the very antithesis of this attitude. While not trespassing on the field of scientific observation and experiment, it is far from being vague and unprecise in its indications of the general direction of intellectual effort. It is the Marxist who knows what to do and how to set about doing it, while the pure intellectual, once the protective shell of his environment is broken, is utterly at sea and easily falls prey to the most unscientific and mystical extravagances.

The Character of Marxist Prediction

The other criticism of Marxism is that it claims to know everything and to predict everything, that it is in fact a return to the teleological systems in which events are determined by the ends towards which they tend rather than by what has happened before. This criticism is itself a reaction to the bankruptcy of the intellectual in the latter days of capitalism. In these days, while natural science is willing enough to predict particular phenomena and is deeply involved in practical industry based on experiments, social science has withdrawn more and more into the sphere of abstract study. The historian of today claims that there is no theory of history and that all he has to do is to describe events as accurately as possible. The economist dissociates himself from actual financial events such as booms and slumps and discusses the theory of an ideal economics which would hold if it were not for the unfair existence of trusts and trades unions. The philosopher gives up once and for all the search for truth and concerns himself only with precision of language. To all of them the concrete actuality of Marxism, its analysis of world history, its discussion of actual economic events, of crises and wars, its claim that even intellectual fashions are economically determined, is a disturbing and shattering challenge. Such pure intellectuals would prefer not to know anything at all than to have such knowledge, precisely because such knowledge is a call to action.

It was from this background that the attack on Marxism as

a dogmatic, ready-made scheme was launched. Now Marx himself from the Communist Manifesto onwards made predictions as to what would happen in human society. There we find:

> The advance of industry, whose involuntary promoter is the bourgeoisie, replaces the isolation of the labourers, due to competition, by their revolutionary combination, due to association. The development of modern industry, therefore, cuts from under its feet the very foundation on which the bourgeoisie produces and appropriates products. What the bourgeoisie therefore produces, above all, are its own gravediggers.

Or in a more generalised form in *Das Kapital*:

> Centralisation of the means of production and socialisation of labour at last reach a point where they become incompatible with their capitalist integument. This integument is burst asunder The knell of capitalist private property sounds. The expropriators are expropriated. (I, ch. xxxii)

True, in his bitter exile in London Marx certainly on more than one occasion hoped for the success of that revolution which he had seen fail in 1848 and was to see fail again so gloriously in 1871. But we must distinguish, as he distinguished, between predicting the outcome of particular events in time and place and that of a general movement in human affairs. A victory for the revolution such as occurred in 1917 was a definitive thing. It gave the first possibility of building up the new stage in human affairs which Marx had predicted. On the other hand a defeat for the revolution left all the contradictions that capitalism has engendered unaltered or even sharpened, it could never be definitive but only the prelude for further struggles. Lenin understood this well and showed his understanding in his own management both of the unsuccessful revolution in 1905 and the successful one in 1917. In any particular event success cannot be assured, but it is only worth refraining from action when success seems totally impossible or premature. To strike at the right time, or to refrain from striking at the wrong time, is to understand the dialectics of the particular situation.

Here again there is a widespread misapprehension of the meaning of Marxism. This ability to understand a situation, to act in it, are not things historically determined in some general and infallible way; they are abilities of actual men at

à particular time, with their individualities, characters, judgment and failings. All important issues must depend on individuals. By all those who have real knowledge of Marxism—and such knowledge is not to be found so much in books as in practical political activity—this is fully realised. But it is also realised that the individual is built up by the situation in which he grows and that the greatest individuals, the revolutionary leaders, represent most completely and most consciously the social forces actuating the great mass of their followers. The leaders are not separate from the people or above them; their strength is drawn from them. Nor is this true just for one or two great leaders. The revolutionary situation places individual responsibility in greater or less degree on hundreds, thousands and millions of men, women and children. The events of the past few years give a complete lie to the idea that Marxism deals only with inevitable movements of masses. During the war in the Soviet Union and among the resistance movements the individual rose to his full stature, and was able to deal by his own initiative, and yet in perfect accord with the general plan, with situations far exceeding any older estimations of human capacity.

Dialectical materialism does predict and its predictions have a force which goes beyond the mere abstract accuracy of its analysis. It deals with a human situation in which human beings are agents as well as subjects. The understanding of Marxism, the consciousness of the movement of society, are themselves most powerful forces working towards the achievement of the predicted ends, and they are powerful precisely because they are conscious and consciously directed. The unity of Marxism in action is an organised unity and its very organstation is an expression of the acceptance, even before its full achievement, of conscious and planned human co-operation.

One hundred years have passed since Marx put out the first sketches of his method, sixty since he died. In those sixty years the great events of which he wrote have begun to happen. The crisis of the transformation which he predicted is with us at this moment. The circumstances of the world situation are vastly different from the apparently stable and expanding capitalism which lasted his time. Nevertheless, so close was Marx to understanding the course of development that his own ideas and methods have suffered far less change

in the interval than those current in intellectual circles over the period. Indeed the other writers of the forties and the sixties of the last century are now only academic curiosities, while the words of Marx seem to apply not only to the present but still more to the future.[1] What was apparent to Marx one hundred years ago was something which seemed highly paradoxical in his time, but the world has been forced to accept, by the march of events, many of the points that then seemed most remote from reality. Who would then have thought, outside the ranks of the Marxists, that economic stability, political liberty and peace were not blessings that humanity was likely to enjoy in greater and greater measure as time went on—

> Till the war-drum throbbed no longer, and the battle flags were furled,
> In the Parliament of Man, the Federation of the World
> (Tennyson, *Locksley Hall*)

Marxism and the Scientific Revolution

What is true for economics and politics is equally true for philosophy and science. In ideas, in organisation, and in rela-

[1] As an example we might take the statement from the Preface of the Russian translation of the Communist Manifesto, which was published in 1888, as a prediction for our own time:

> There is no mention there [in the original edition of the Communist Manifesto] indeed of either Russia or the United States. It was the time when Russia constituted the last great reserve of European reaction and when emigration to the United States absorbed the surplus forces of the European proletariat. Both countries provided Europe with raw materials, and served at the same time as markets for the sale of its manufactured goods. Both appeared therefore, in one way or another, as pillars of the European social order.
>
> What a change has taken place since then! Precisely European emigration has promoted the enormous growth of agriculture in North America, which through its competition is shaking the very foundations of the great and small landed properties of Europe. At the same time it enabled the United States to begin with the exploitation of its vast industrial resources, and at that with such energy and on such a scale that, before long, it must put an end to the industrial monopoly hitherto exercised by Western Europe. These two circumstances react in their turn upon the United States in a revolutionary direction. More and more do the small and medium-sized holdings of the independent farmers, the basis of the whole political system of America, lose ground before the competition of gigantic farms, while at the same time a numerous proletariat is emerging for the first time in the industrial regions alongside of a fabulous concentration of capital.
>
> Let us now turn to Russia. At the time of the Revolution of 1848–9, not only the European monarchs, but the European bourgeoisie as well, looked upon Russian intervention as the only salvation from the proletariat, which was then for the first time becoming aware of its own strength. The Czar was acclaimed the leader of the European reaction. To-day he sits in Gatchina, a prisoner of war of the revolution, and Russia forms the vanguard of the revolutionary movement in Europe.

tion to economic and political factors, the trend of modern science is more and more towards the approximation of Marxism. What is interesting is that this approximation was usually spontaneous, that is, it arose out of the development of knowledge of and control over natural forces and the interplay between this development and that of economic and political forms. If Marxism had been able to penetrate more rapidly into scientific circles, these results would have been obtained more clearly and with less trouble: but coming as they do, they provide a remarkable and independent confirmation of the fundamental rightness of the Marxist view. That science should reflect the social and economic atmosphere of the time, both in the balance of its interest in different parts of the universe and in the mode of expression of its discoveries, is a view that is now coming to be generally accepted. It is easy for us, for instance, to see in the original formulation of Darwin's *Origin of Species* the clear reflection of the free-for-all competition of the nineteenth century. Indeed Darwin himself always admitted his debt to Malthus in the formulation of the concept of the survival of the fittest. At the time, however, this resemblance came to be used the other way round, and morals drawn from the supposed struggle for existence in nature were used to justify the more anti-social features of early capitalism, a tendency of which Herbert Spencer will remain a permanent caricature, and which was later to be the foundation of the Nazi race theory.

Now science in the last sixty years, and particularly since 1895, has undergone a revolution at least as great as its revolutions in the middle of the seventeenth and at the end of the eighteenth centuries—the revolution associated with Galileo and Newton or that associated with Lavoisier and Dalton. Since 1895 the atomic structure of matter has been proved in detail; the quantum and relativity theories have been elaborated; chemistry has become part of physics; and the progress of biochemistry and genetics has reduced much of biology to chemistry and mathematics. In most ways discoveries of the last half-century have brought us far closer to the practical and realisable knowledge of the behaviour of inorganic and organic systems than all the previous discoveries of science put together.

The Atomic Age

This great revolution of knowledge has already reached a culminating expression in the making and the using of the atom bomb. The bursting of the bomb over Hiroshima expressed at the same time the enormous new power to control nature which science has given mankind, and the utter and criminal incapacity of the old order to use it for anything but horror and destruction. The use of atomic power coupled with all the other developments of modern science represents a step in human control over nature far greater and far more sudden and revolutionary than any in the past history of the planet: greater than fire, greater than agriculture. It demonstrates that the only limit to human capacity is to be found in society and not in nature.

Paradoxically, however, inside science this increased knowledge, these new and verifiable relations that have been established, far from revealing a more regular and coherent picture, have had the opposite effect of disturbing and breaking up the scientific system which Newton had blocked out and to which the nineteenth-century scientists thought they were putting the final touches. The new advances of science have led to the most searching criticism and revision of the foundations of science, a criticism which is still in full swing.

If we explore the nature of the revision of ideas that has come about, we will find that most of those ideas are of a fundamental philosophic character. They do not affect the practical predictions of science but they do affect its original foundation. They all seem to tend in the same direction, which is away from what would have been called in the nineteenth century the common-sense, materialist view of science. Now this kind of criticism very naturally has led a number of people—and among them a number of eminent scientists—to abandon everything and fall pell-mell into mysticism and superstition.[1] Their philosophical world, for all that they would not admit they had one, was built on a dualistic basis: there were two worlds, a world of hard fact in which millions of atoms were attached firmly by forces that obeyed Newton's laws; and a world of fancy, religion and morals which either obeyed no laws or took them from the Bible.

[1] See Sir James Jeans, *The Mysterious Universe*.

The Unity of Science

Modern developments in science have made this position untenable. The hard world turns out to be just that region of experience which has some relation in scale to our immediate bodily experience. We know how a table or a billiard-ball behaves because it is about the right size for us. We try to make atoms and nebulae behave in the same way, and if they do not we say the universe is becoming unreasonable. In expanding our range of experience, science has shown that each level of magnitude, each level or order or complexity, has its own laws. Our common-sense laws are only laws for a little part of the universe, although this is the part that matters or has mattered most to us.

At the same time, social studies of anthropology, history, economics, but most of all, perhaps, pyschology, have shown us that the human or spiritual world is not governed arbitrarily by unalterable human nature or divine institutions, but has its own far more complex laws of development and behaviour. These two worlds are not really separate but regularly merge into each other. We can take the behaviour of animals, for instance, on one side to illustrate beautifully physico-chemical nervous reactions, and on the other to parallel human emotional and intellectual performances. In this sense of the unity of science, the whole tendency of modern knowledge is in the direction which Marx was one of the first to emphasise. The working scientists of today find the dualistic attitude increasingly difficult to maintain. They see success in their own fields dependent on close co-operation and understanding of scientific work in all other fields. They begin to sense the importance of historical and social studies in guarding them against prejudices in their own work and pointing towards possibly fruitful research.

Dialectics in Physics

Other aspects of dialectical materialism find increasing reflection in the internal development of the sciences. The greatest and most difficult breach in the common-sense point of view is found in modern physics. The modern physical-world picture is full of antitheses and opposites and is a standing

example of the failure of the older logic. A critical instance is that of the nature of radiation. For many years controversies were waged as to whether light consisted of particles or waves; now we know that not only light but also electrons and atoms themselves have both waves and particles at the same time, or rather, they are something that can be a wave or a particle. The difference between these concepts is that a particle is something that is somewhere at a specific time and a wave is something happening over a certain space for a certain time. The distinction between them seems easy enough to common sense but we know now that we can never be specific enough about a particle's position and that contrariwise a wave can be located. The opposites here completely interpenetrate.

Another illustrative example is what we now call the co-operative phenomena of physics in which a process such as the melting of a solid appears no longer as the property of a particular atom but as the property of a group of atoms in virtue of their common mutual interactions. Beginning with one atom, we can think of its movements disturbing its neighbours, but the moment its neighbours are disturbed, the constraint on the original atom is reduced, and when the movement is large enough the whole system falls apart or "melts" as we say in ordinary language. Now the interesting thing here is that it is quite arbitrary which atom we start from. The characteristic of melting depends on the general pattern and not on any particular part of it. It is communal property, the property of the system as a system. Co-operative phenomena are an illustration both of the character of qualities which arise from quantitative conglomeration and of the critical changes of quality which occur as the result of steady quantitative change. It is aspects of physics like this that make it much easier now than it was fifty years ago to understand and accept dialectic views.

Historical Elements in Physics

Perhaps the most striking of all is the appearance of the historic element. Physical laws used to be considered, in contrast to those in biology or society, immutable: the material basis, the elements of physics, permanent; they represented the embodiment of the Platonic ideals. But, beginning fifty years ago with the discovery of radio-activity, we have seen physics

itself change gradually into just such a relative and evolutionary state to which Darwin, forty years before, had brought biology. In the last few years the studies of nuclear physics, cosmic rays and cosmology have combined into one grand synthesis in which the nature of the physical world is seen to embody the results of great and really historic transformations of the universe: thousands of millions of years ago, it is true, but still at a definite time in the past. The elements themselves show, by their relative abundance and scarcity on this earth, the characteristics of the enormously concentrated, dense and hot universe in which they were formed before there were such things as stars and galaxies. These in turn were formed by an explosion which by scattering them prevented all but insignificant further change in the atoms, or, as we say, froze their equilibria, and at the same time gave us the expanding universe in which we live today. Modern cosmogony has provided in these sudden transformations between widely different states, two or three more stages of dialectic transformation of hierarchical order to add at the beginning of the series which Marx and Engels blocked out. As science progresses we may discover still more at the beginning, and, by our own efforts, add more at the end. What the advance of modern physics has taught us is that laws are not absolute and eternal truths, except in so far as they are tautologies illustrating our incapacity to detect at once two different ways of saying the same thing. They are relative and developing relations, not only in respect of our discovery of them but in respect to actual historical evolution of a material universe.

Dialectics in Biology

Very similar tendencies have been active in modern biology. The balance of chemical and nervous factors in the behaviour of organisms is very difficult to formulate on old-fashioned, materialist lines, but the alternatives of postulating entelechies and wholes has seemed far too animistic and magical to suit the working scientist, however much it might appeal to his more religious-minded seniors. Here again the dialectic pattern breaks up the behaviour of an organism into the conflict between the effects of ascertainable factors, furnishes a more promising approach and points to appropriate experimentation.

This is particularly useful in the field of genetics.[1] Here, since the discovery by Morgan of the chromosome explanation of Mendel's law, there has been a tendency to attempt to account for every aspect of the organism as a direct result of its gene pattern and exalt the importance of inheritance over environment. This was the high-water mark of simple materialism applied to biology. But work of recent years has shown the reality to be much more complex. The gene now appears as only one set of factors which, combining with other physical and chemical effects in the organism's development, pilot that development along one of a number of different tracks. The interaction between the chromosome and environmental influences at each stage gives rise to a consequent interaction of other genes and other environmental factors at a further stage; the normal development of every individual organism becoming thus a dialectic process throughout.

What holds in the field of the development of the organism also holds in its behaviour patterns and their response to external stimuli. The work of Pavlov and his followers has brought out the complex inhibition and release mechanism that underlies normal bird and animal behaviour. That in turn links in with our knowledge of human education and the response of the individual to the society which moulds him and which he helps to transform.

It is becoming more and more clear in biology that we are approaching a great new clarification and synthesis corresponding to that which has occurred in physics, and this synthesis is likely to be intrinsically dialectic and historical in character. Recent researches in biochemistry and biophysics have shown us an extraordinarily complex and detailed identity between basic processes going on in all forms of life, from the simplest cell to the cells in an oak tree or the human being: the same amino-acids, the same enzymes, the same structure of the nucleoproteins associated with formation of simpler proteins. Modern research is more and more confirming the postulate of Engels that life is "the mode of existence of the proteins." Now we can go further; the common chemical peculiarities of life, just like the peculiarities of the elements, point to a historic common origin. We cannot any longer doubt the existence of a phase of chemical evolution preceding

[1] See J. B. S. Haldane, *Marxist Philosophy and the Sciences.*

the elaboration of tissues and organs characteristic of most life in the world today. Here there is a complete and dialectical union between the study of the structures themselves and that of their genesis. The history of life is written in its actual chemical constitution. These molecules, reproduced for the most part identically for a thousand million years or more, are living fossils and the studies of the phenomena of life and of the origin of life are now inextricably merged together.

Dialectics in the Social Sciences

Marxism has its roots in the social sciences and it is there that not only the intellectual views of Marx and Engels, but even more the actual consequences of the social evolution which they predicted, have influenced and transformed our knowledge. It is in fact becoming more and more evident that there is no social science outside Marxism. The old economics has broken down with the disappearance of the system of free competition which was considered to be the natural order of things, and which Marx showed was just one stage that had come into existence and would pass away. Anthropology, archaeology and history are now tending to merge into one study of human social development where economic determinism is becoming more and more recognised as the guiding clue. Psychology itself is tending to lose its highly individualist character, which was put on it by the practical necessities for dealing with the mental ailments of the idle rich. The influence of social factors in the general moulding process of society on the individual becomes the key to the understanding of the human mind. Here again the fundamental Marxist concept of the importance of historic development on existing forms is evident. Our very intellectual and emotional reactions are themselves mental fossils attached to definite historic events in the past, and transmitted, not by any mysterious group soul, but by the normal mechanism of cultural transmission in the family, the school and the workshop: mechanisms which can be understood and ultimately controlled.

The Value of Marxism in Scientific Research

All these examples can do no more than indicate how the scientist of today finds it almost inevitable to deal in dialectic terms even though he may not be clearly aware that he is doing so, or may repudiate any suggestion of Marxist influence. A convinced anti-Marxist, however, might point out that all this will not take us very far because the great bulk of the scientific discoveries of modern times were not made by Marxists or by those influenced by Marxist thought. This is indisputable, but it does little more than show the inevitable tendency of the convergence of human thought under similar social influences. The fact that it is perfectly possible for a non-Marxist to arrive at a Marxist conclusion may be taken as an independent indication of the usefulness of the Marxist viewpoint, but it can never be proof that it would not be far easier and quicker to arrive at that conclusion by conscious application of Marxist principles.

The scientists of today can no longer afford to ignore Marxism or not to avail themselves of methods of thought which, when fully absorbed by understanding and practice, will lead to a new leap forward in our collective capacity for understanding the world and thus for dealing with our physical and social problems. Until now, outside the Soviet Union, there has only been a small handful of scientific workers who have had more than a smattering of Marxist theory, and among those few the Marxist views were only coming to be appreciated in the years preceding the war. In spite of this, many Marxists such as Joliot-Curie, Haldane or Gordon Childe are men of note in their professions.

It is, however, in the Soviet Union that we can see the first results of the application of dialectical materialism in science. The actual scientific work that goes on in the Soviet Union is carried out using the same type of apparatus and the same inner logic of analysis and induction that we find in science in other places and at other times. Dialectical materialism is not a substitute for the rigours of scientific method. It enters into science to point the way towards what is to be discovered and to provide the means for making these discoveries effective. In other words it is more concerned with the strategy than with the tactics of scientific advance. That is not to say that it has

nothing to do with the detailed scientific work, but its influence here is indirect. The good Marxist should be able to see more clearly, should be able to avoid the preconceptions and conventional views that prevent people seeing things, even when they are under their noses.

The Planning of Science

Marxism is not and does not claim to be a universal method for making discoveries in detail. The human individual qualities of carefulness, honesty and imagination are still as necessary as ever. Where dialectical materialism is most useful is in the choice of field, the direction of attack in that field and the linking up with other workers in the same or different fields. It is in fact the philosophy of planned scientific advance to supersede advance by numerous individuals each following his own track and supporting each other, consciously by adding to the scientific tradition and unconsciously by following socially dictated tendencies. That is not to say that the greater scientists have not from the beginning of science planned their work. Some even, as Pasteur, have been able to build around themselves a group of workers dividing up the field between them. These individual efforts have, however, been isolated and impermanent.

Science as a whole has had its ups and downs. Achievements in separate subjects show even more violent fluctuations. The determining factor for the advance of this or that subject has been the relation between what is discovered and what is used. Scientific research in certain fields is directed by social and economic needs, and this research in turn produces effects which have economic and social consequences; though often only after an enormous time-lag. One hundred to one hundred and fifty years may elapse between the first scientific impulse and the final full-scale practical result. Thus the beginning of large-scale chemical manufacture of the seventeenth and early eighteenth centuries promoted lively interest in chemistry. This was pushed with vigour up to the nineteenth century, but only began to give returns to industry in a big way with the growth of the scientific chemical industry, particularly with the dyeing industry at the end of the nineteenth century. This casual process, before the Soviet Union showed that it was not

necessary, was considered, like the survival of the fittest or free competition, to be a law of nature, something that must not be interfered with for fear of upsetting its delicate mechanism. We know now from our own experience in wartime that these enormous time-lags can be reduced quite simply by proper organisation and planning of science, or by two-way linking of research, development and production, through which production problems can pass back to research and out again through development. But it is quite impossible to plan scientific research without planning it in relation to a definite system of demand and to find that implies a social analysis. Only if we start with social analysis can we say what part science has to play and how it can play it. It is in this wider sense that dialectical materialism provides the major directive to scientific advance.

Science in the Soviet Union

It is not only or even mainly with the analysis of past and present science that the value of dialectical materialism makes itself felt; it is rather in its indications for the future. For the science of the future, socially directed planning will be an absolute necessity; the type of that planning we can see already in the Soviet Union. It was only through the conscious application of Marxist theory that it was possible to build, on the narrow foundations of Czarist science, the vast, integrated and vital organism of modern Soviet science. In a generation a nation of illiterates is becoming a nation of scientists, and this has been proved both in peace and in war. It is not a question of having merely a small, scientific élite, of advancing the frontiers of knowledge here and there, but of the establishment of a universal practice of treating all problems of production, agriculture, health and strategy as requiring scientific answers on the basis of controlled experiment and statistical results.

The various plans of the Academy of Science, culminating in the great post-war five-year plan of 1946, show the form of the relation between fundamental science and the needs of the country. The plan is drawn up by the scientists themselves tracing out the inner needs of the different scientific disciplines and knitting them together in a whole which has a coherence of its own as well as numerous links with industry, agriculture

and medicine.[1] The contribution of dialectics is to be seen in this analysis. The fruits of Soviet science are already apparent in the practical successes of the Soviet Union, but they are only the first-fruits. What has really happened is that a whole people are learning this new dialectical way of dealing with material and social questions, and that whatever the destruction caused by the Nazis, they have consequently in themselves not only the will but the means to produce new knowledge and new achievements.

The organisation of science in the Soviet Union is not a restrictive but a liberating organisation; it employs more people to do more things; it discovers and utilises natural resources; most of all it utilises what we are now coming to understand as the greatest and most powerful of all natural resources, man's own capacities and intelligence. There is a latent possibility in every man or woman of every race and culture to contribute something, little or much, to the advancement of human culture.

What we have seen now for thirty years of struggle and development in the Soviet Union, we are beginning to see in the rest of the world. Since the liberation of Europe from the Nazis and the partial and still uncertain liberation of the colonial countries, there is apparent everywhere a new urge to make use of planned science as the most rapid, as well as the most effective and lasting, way of raising the standard of living and achieving a civilisation free from the insecurity of a selfish and grasping capitalism. Everywhere, even in the capitalist countries themselves, the idea is growing of leading science in an organised way to the solution of human needs. It is being opposed, naturally enough, by reactionary forces, in this field as in others, masquerading under the name of freedom. But the freedom of anarchic capitalism is illusory and self-destroying; it is a freedom for exploitation and not for creation. Through the failure to realise this, the great work of the eighteenth-century liberals broke down.

Marxism and Freedom

The freedom appropriate to our stage of development is one of co-operation and not of competition. Men are to be liber-

[1] *The Soviet Journal* (published by the Society for Cultural Relations with the U.S.S.R.), Autumn 1947.

ated by knowing their own limitations and not by ignoring them: by accepting the necessity of working together and not insisting on 'rugged individualism' in an age which has outgrown it. The framework which will help to guide this co-operative effort is the framework of Marxism. This is not a rigid shell, fixing for ever like a written constitution the future progress of human intellectual and practical achievements; it is rather a scaffolding which will be taken away when it has served its purpose. But that time is not yet and much has to be gone through before it is reached.

Today, Marxism is a growing philosophy; it is the only live philosophy and it is still young. There are major tasks ahead on the intellectual side just as there are in economics and politics. It is no longer sufficient to possess pieces of knowledge about the material or biological universe or even to have a straightforward method like the classical method of science for solving certain types of problems. All our knowledge requires to be integrated and understood in terms of the human society out of which it has grown and which it helps to transform. There is a detailed and vast programme of research and interpretation before Marxist physicists, biologists and humanists of today and tomorrow.

The old dualist conception implicit in the development of science since the Renaissance needs to be broken down—and broken down on both sides. We need to show in detail the human and social elements that enter into the development of physical science, but, on the other side, we need the revaluing through scientific analysis of many social terms and attitudes we have borrowed and modified unconsciously from the distant past. The revaluation of values must accompany the socialisation of knowledge. Men feel, with a sound instinct, that there is something real and significant in such virtues as truth, courage and the love of country, and as these virtues are traditionally associated with religion and patriotic myths, they will cling to these myths rather than abandon the values they pretend to explain, but in fact only restate in other and more solemn words. It is for Marxism to give the reality of social values a fuller content and to provide them with bases that are acceptable in this conscious and rational stage of human development. Here, theory and practice must march together. Only by creating a new world, free from the inequality and

exploitation which had turned the traditional values into the grossest hypocrisy, can we expect them to be transformed into new and genuine human aspirations.

But the time for that is not to be relegated to a distant future: it is here and now. The struggle of the war itself was one which called for enterprise and understanding in every field of activity—at the front no less than in the factories and in the fields. Old ways of doing things and old ways of thinking were scrapped as being intolerably inefficient and slow; a greater transformation took place in these few years than in half a century of peaceful capitalism. It was precisely here at the urgent tasks of war and resistance that dialectical materialism showed to its greatest advantage. It will be needed even more in the difficult times through which we are now passing; needed to combat the false divisions that reaction is trying to impress upon the world. Only Marxist understanding can show that the banner of Western Civilisation which is being unfurled for a new war of annihilation is the same old swastika banner of capitalism under which Hitler and Goebbels tried to rally deluded people for a crusade against Bolshevism. There is only one civilisation, of which all are heirs: that civilisation is now undergoing the transformation which Marx and Engels predicted one hundred years ago. What is fading away is the old bourgeois domination of that society and, in attempting to bolster up this dominance, the forces of reaction are threatening once again to use war as a last resort to protect their untenable positions. The enormous forces which modern science provides, and which now more than ever before assure every human being of the conditions of a good life, are being deliberately held back by these reactionary forces and diverted in secret to preparations for war. They can only succeed in the measure that the peoples of the world fail to understand the real nature of the situation.

It is only through Marxism that it is possible to see every situation in the light of the larger movements of history and thus to make its solution one integrated part of a joint movement. For the value of Marxism lies not so much in solving particular problems as in showing what problems there are to solve and which of them should have the greatest priority. It is not an abstract system into which the future has to be fitted, but a live and flexible method by which we can ourselves determine it.

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